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ABSTRACT

This electronics curriculum is intended to provide instructors of electronics with a useful guide for relating important new technological advances to the vocational classroom. The competency-based learning activity guides are written to be used with any electronics equipment available at the secondary and postsecondary levels. Instructors must add specific instructions for operating their own equipment. The 117 guides --one per task--are divided into 11 units: analyzing DC circuits, analyzing AC circuits, analyzing solid state devices, analyzing analog circuits, analyzing digital electronic circuits, performing microprocessing operations (1 and 2), performing lab practices, recording and reporting technical material, using technical references, and introduction to control systems. Each guide consists of an overview (specifying task, purpose, objective, estimated class time), a list of learning steps, a list of resources, information sheet(s), activity sheet(s) with answer sheet(s), performance/product checklist, and examination with answer key. Appendixes include an analysis of the science and mathematics concepts considered prerequisite or co-requisite to understanding the content of the electronics course, a crosswalk--an electronics cluster matrix (relating tasks to sections of the curriculum guide), and a listing of employability skills. (YLB)

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ELECTRONICS

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EMPLOYMENT

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Competency-based vocational electronics currivulum

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FOREWORD

This Electronics curriculum has been developed to provide instructors of electronics with a useful guide for relating important new technological advances to the vocational classroom. The competency-based learning activity guides are written to be used with any electronic equipment available at the secondary and post-secondary levels. Each instructor must add to the existing activity sheets specific instructions for operating their own equipment.

Illinois teachers developed these instructional materials during the summer of 1985 based on information obtained from the electronics industry. The curriculum was field-tested in 20 secondary and post-secondary schools during the 1985-86 school year.

The Illinois State Board of Education is committed to assisting Education for Employment regions in the development of quality vocational education programs. The activities outlined in this product have been designed to better prepare persons for employment and/or further education in the field of electronics.

Sincere appreciation is extended to the vocational educators and industry representatives who assisted in the development and field-testing of this curriculum.

Ted Sanders

Ted Sanders
State Superintendent of Education

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ELECTRONICS

ANALYZING DC CIRCUITS

A 1: IDENTIFY SOURCES OF ELECTRICITY

TASK:	Identify various sources of electricity.
PURPOSE:	Today's electronics technician must have a thorough understanding of all electrical principles, including the methods of producing electricity from other forms of energy. In this learning guide you will be introduced to various sources of electricity.
OBJECTIVE:	Given a written exam, you will identify various sources of electricity. To master this task, you must score 80% on a written exam.

ESTIMATED CLASS TIME: 4 HOURS

SOURCES OF ELECTRICITY

LEARNING STEPS

A 1

READ: Information on "Sources of Electricity" in Information Sheet A 1.1

READ: Information on "Sources of Electricity" from the following resource list. See your instructor.

VIEW: Audio/Visual material on "Sources of Electricity." Contact your instructor.

COMPLETE: Activity Sheet A 1.2 on "Sources of Electricity."

COMPLETE: Lab Performance on "Sources of Electricity." Contact your instructor.

COMPLETE: Performance Checklist A 1.3. Contact your instructor.

REVIEW: All material covered in this learning guide and information presented by your instructor.

COMPLETE: Written Exam A 1.4. Contact your instructor.

SOURCES OF ELECTRICITY

RESOURCES

A 1

1. BASIC ELECTRICITY AND CIRCUIT CONCEPTS: VOL. 1, DC CIRCUITS, Oliva and Dale (Radio Shack: Texas Instrument Learning Center, 1979), 4th Edition. Chapter 1.
2. DC ELECTRONICS (Heathkit Educational Systems, 1984). Units I & II.
3. BASIC ELECTRONICS, Grob (McGraw-Hill, 1984). Chapter 1.
4. INTRODUCTION TO ELECTRICITY AND ELECTRONICS, Bell & Howell Schools (DeVry Institute of Technology, 1984). Chapter 1001.
5. INTRODUCTION TO INDUSTRIAL ELECTRICITY-ELECTRONICS (Oklahoma Trade and Industrial Education).
6. ELECTRONICS: PRINCIPLES AND APPLICATIONS, Badrkhan and Larky (South Western Pub.). Chapter 1.
7. ELECTRICITY ONE-SEVEN, Mileaf (Hayden). Chapter 1.
8. ELECTRONIC COMMUNICATION, Schrader (McGraw-Hill Pub. Co.). 5th Ed. Chapter 1.

INFORMATION SHEET

A 1.1

IDENTIFY SOURCES OF ELECTRICITY

To understand the field of electricity/electronics, you have to start with some fundamentals. Electricity/electronics is an "end result of science and math principles, and often lends itself to an easy understanding of "why" and "how" devices work. Something that seems extremely difficult to understand, such as a computer, may be easy to understand with a thorough training in basic electricity/electronics.

To begin, we must clarify the difference between electricity and electronics. A generally accepted definition of electricity is:

Using the flow of electrons to do work.

An example would be a toaster, iron, or washing machine. All of these items are electrical in nature, and help man everyday.

Electronics, on the other hand, goes one step further than electricity and offers communication and feedback between person and machine. We say:

Electronics is electricity that has intelligence.

Some examples are the computer, television, and radio.

ELEMENTS, ATOMS, AND ELECTRONS

Elements are the building blocks of all matter. Silver, gold, copper, hydrogen, and oxygen are all common elements. An atom is the smallest part into which an element can be divided. It is also the smallest piece of an element that will still act like that element. To date, there are 106 different elements known.

All matter is made of molecules and atoms, and all atoms contain electrons. Each atom has at least one proton, neutron, and electron. An electron has a negative (-) charge while the proton and neutron (together they're called the nucleus) have a positive charge (+). An electrostatic field holds the electron in its orbit around the nucleus much like the earth orbits the sun. The electrostatic field creates what are called "lines of force." These lines of force have an effect on the electrons that they come in contact with. See Figure A 1.1-1.

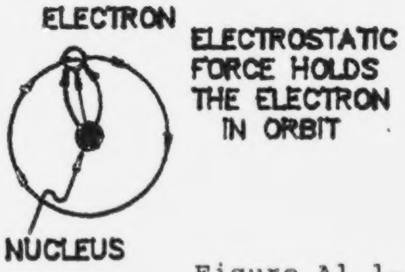
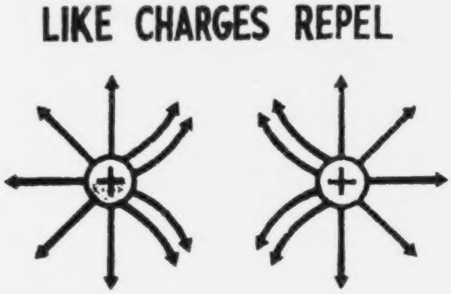

ELECTRON
ELECTROSTATIC FORCE HOLDS THE ELECTRON IN ORBIT
NUCLEUS

Figure A1.1-1

LAWS OF ELECTROSTATICS

1) Like charges repel each other.
2) Unlike charges attract each other.
See Figures A 1.1-2 and A 1.1-3.


LIKE CHARGES REPEL
+
+

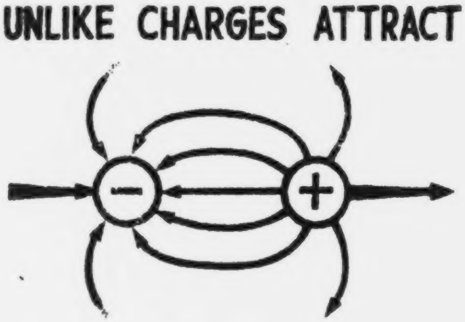

UNLIKE CHARGES ATTRACT
−
+

Figure A1.1-2

Figure A1.1-3

The path which the electron takes around the nucleus is called an "orbit." (Electrons travel at about the speed of light!) Several electrons travelling in the same orbit are said to be in the same "shell." The shells that are formed around the nucleus can hold only a certain number of electrons before another shell is formed. When an atom has eight electrons in its outermost shell, the atom is very "stable" and is resistive to any changes in its atomic structure. In order to produce electricity, the atom must be in its unstable state (less than 8 electrons in its outermost shell).

VALENCE SHELL

What is a "valence" shell? It's the outermost shell around the nucleus. A new shell is formed whenever a "valence" shell is filled. In the valence shell, electrons can break away from the atom more easily, than in any other shell. When they break away, they're called "free" electrons. These "free" electrons move about looking for new shells as their home. When they find a new shell, a different element can be produced.

Some elements that have only 1 or 2 electrons in their valence shell "give away" electrons very easily; they're known as conductors (i.e., gold, silver, copper). Other elements that have 6 or 7 electrons in their valence shell "steal" electrons very easily; they're called insulators (i.e., chlorine, iodine, tungsten). Still other elements, such as germanium and silicon which have 4 electrons in their valence shell, are neither conductors nor insulators. They are called semiconductors. Today, semiconductors are the foundation for all microelectronics technology.

When an atom becomes "active" and it loses or gains an electron, it's called an "ion." Atoms that lose electrons are called positive ions, and those that gain electrons are called negative ions.

To form material such as copper would take billions and billions of atoms. There's an easier way to express such a large quantity of electrons. That is:

1 COULOMB = 6,250,000,000,000,000,000 electrons.

Another way to write this is: 1 COULOMB = 6.25 x 10^{18} electrons. One coulomb of charge is an extremely large number of electrons and is a common unit used in specifying how big or small a given charge is.

The movement of electrons through a conductor is called "current."

Current is the flow of electrons. Since no work can be done electrically unless there is electron flow, current becomes very important.

Energy is the ability to do work. Energy can be transformed from one form to another. There are two basic kinds of energy: kinetic (energy in motion) and potential (stored energy).

When there is a difference of potential energy, it is known as an EMF (electromotive force) or voltage. There must be a voltage to produce a flow of electrons. A voltage is commonly referred to as the "push" needed in a circuit to move the electrons that are at rest (potential energy) into motion (kinetic energy).

Potential energy (which from now on we'll call "voltage") can develop in many different ways. There are various sources of electricity.

SOURCES OF ELECTRICITY

	Source	Example
1.	chemical action	dry cell, storage battery
2.	magnetism	generator, alternator
3.	friction	static
4.	heat	thermocouple
5.	light	photoelectric cell
6.	pressure	quartz crystals, Rochelle salts

Chemical Action - a chemical reaction produces opposite charges on two dissimilar metals, which serve as the negative and positive terminals. Cells can be produced and, when many of them are combined, a battery is formed.

Magnetism - any moving charge has an associated magnetic field; also any changing magnetic field can produce current. A motor is an example of how current can react with a magnetic field to produce motion; a generator produces voltage by means of a conductor rotating in a magnetic field. When electricity and magnetism are combined, they are called "electromagnetism."

Friction - electrons in an insulator can be separated by the work of rubbing to produce opposite charges.

Heat - some materials when heated can release electrons from the surface. These emitted electrons can be controlled to provide useful applications of electrical current.

Light - some materials are photoelectric, meaning they can emit electrons when light strikes the surface. Other materials capture light and manufacture energy to be used later.

Pressure - when pressure is used with specific materials, the result is a voltage. As an example, when a wafer of quartz crystal is placed between two metal plates and a pressure is applied to the plates, a potential difference develops between them (Piezoelectric effect), i.e. stereo cartridge, microphone, quartz watch.

Energy sources can only be effective when given a chance to release their potential. Therefore, a means of releasing the energy has to be found. One way electricity can leave a power (energy) source is by connecting wires. Wires are called conductors. Any material that allows electrons to move through it with relative ease is known as a conductor.

Next, a "load" is needed - something that uses electricity. A load is the device that absorbs power and converts it into a desired form. Resistance - which limits the flow of current - is present when loads are used. Every load has resistance.

When a power source, a conductor, and a load are connected together they are called a circuit.

All power sources are not created equal. There are two kinds of electricity used and they are:

1. Direct current (DC)
2. Alternating current (AC)

Some power sources are DC in nature, while others are AC. What's the difference between AC and DC?

AC is produced when an electric current flows in one direction in the circuit for an instant, then changes direction and flows in the opposite direction.

DC is produced when an electric current flows in only one direction. Electrons flow from the power source's low potential terminal (-) travelling through the circuit and back to the power source's high potential terminal (+). The low potential is usually referred to as "negative" and the high potential "positive." Each DC power source will have a negative and positive terminal.

To become more familiar with the terms and definitions covered in this learning guide, review: "TERMS AND DEFINITIONS."

INFORMATION SHEET A 1.1 CONT'D.

TERMS AND DEFINITIONS

Atom - Smallest particle of an element; particles that bind together to form molecules.

Atomic bonding - Linking together of two or more atoms to form molecules.

Negative Ions - Atoms or molecules having extra electrons causing them to have a negative charge.

Positive Ions - Atoms or molecules that have lost electrons, causing them to have a positive charge.

Charge - Condition or state of having excess or insufficient number of electrons; causes the atom or molecule to be negative or positive.

Compound - Substance made of two or more elements.

Crystal - Material in which atoms and molecules are rigidly held in a distinct, orderly arrangement.

Electron - Negatively-charged particle that orbits around the nucleus of an atom.

Element - One of 106 known chemical substances that cannot be divided into simpler substances by chemical means.

Impurity - Foreign materials that enters into an otherwise relatively pure substance.

Ion - Atom or molecule that has an excess or insufficient number of electrons and, thus, is electrically unbalanced or charged.

Molecule - Smallest particle of a compound; made of two or more identical or different atoms.

Negative - Electrical charge of the electron; attracts protons.

Neutron - Neutrally-charged particle found in the nucleus of atoms.

Nucleus - Core of the atom composed of protons and neutrons around which electrons orbit.

Valence ring - The outermost shell of the atom.

Valence electrons - Electrons that orbit in the outer shell (valence shell).

Proton - Positively-charged particle found in the atom's nucleus.

Positive - Electrical charge of the proton; attracts electrons.

Shell - Spherical surface formed around the atom nucleus by electron orbits at distinct distances from the nucleus.

ACTIVITY SHEET

A 1.2

IDENTIFY SOURCES OF ELECTRICITY

DIRECTIONS: Complete each question. DO NOT CONTINUE with any portion of this guide until the Activity Sheet has been completed. If you need any help, see the instructor.

1. Draw an atom that has 1 proton, 1 neutron and 1 electron and label each.

2. Name 6 ways electricity can be produced.

   1.
   2.
   3.
   4.
   5.
   6.

3. Name 4 devices that are used as power sources.

   1.
   2.
   3.
   4.

4. What is a valence shell?

5. Name 3 elements that are conductors.

   1.
   2.
   3.

ACTIVITY SHEET A 1.2 CONT'D.

6. What is a semiconductor?

7. Complete: Like poles _______________ each other; unlike poles _____________ each other.

8. How many electrons does it take to make 1 Coulomb of charge?

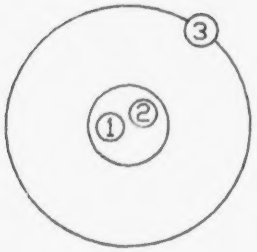
9. A(n) _____________ has a negative charge, and an _____________ has a positive charge.

10. What keeps an electron in its orbit around the nucleus?

ACTIVITY SHEET A 1.2

ANSWER SHEET

1\.



1. proton
2. neutron
3. electron

2. Chemical, light, heat, magnetism, pressure, friction

3. Battery, solar cell, stereo cartridge, quartz crystal, etc.

4. The outermost shell of the atom. It can contain up to 8 electrons.

5. Copper, gold, silver

6. A semiconductor is an element that has 4 electrons in its valence shell.

7. Like poles repel each other; unlike poles attract each other.

8. A coulomb is 6.25×10^{18} electrons.

9. An electron has a negative charge; and a proton has a positive charge.

10. Centrifugal Force and the electrostatic field that is developed around the nucleus.

PROGRAM: ELECTRONICS

TASK: SOURCES OF ELECTRICITY

TASK # A 1.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE __________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT __________

TERMINAL PERFORMANCE OBJECTIVE:

IDENTIFY VARIOUS SOURCES OF ELECTRICITY.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

SOURCES OF ELECTRICITY

A 1.3

CRITICAL ITEMS		ITEMS TO BE OBSERVED	RATING YES/NO
	1.	Was the circuit wired according to the schematic?	Y N
*	2.	Does the circuit function properly?	Y N
	3.	Was necessary data recorded?	Y N
	4.	Was the correct equipment used?	Y N
*	5.	Was the equipment used correctly?	Y N
*	6.	Were safety precautions followed?	Y N
	7.	Was the equipment returned to proper storage area?	Y N

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

STUDENT'S SCORE ____

SOURCES OF ELECTRICITY

EXAM

A 1.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Sources of Electricity. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer a minimum of 8 out of 10 items correctly, 80%.

SOURCES OF ELECTRICITY

EXAM

A 1.4

1. An atom or molecule that has an excess or insufficient number of electrons and, thus, is electrically unbalanced or charged is called ____________________.

   A. an ion
   B. a neutron
   C. an element
   D. an atom

2. A(n) ________________ is a spherical surface formed around the atom nucleus by which electrons orbit at distinct distances from the nucleus.

   A. proton
   B. shell
   C. ion
   D. semiconductor

3. __________ is the flow of electrons.

   A. electronics
   B. bonding
   C. voltage
   D. none of the above

4. A(n) ________________ is material through which electrons flow easily.

   A. insulator
   B. nucleus
   C. charge
   D. conductor

5. Like poles __________; unlike poles __________.

   A. attract; attract
   B. attract; repel
   C. repel; attract
   D. repel; repel

6. Which is a source of electricity?

   A. light
   B. element
   C. current
   D. all of the above
   E. none of the above

EXAM A 1.4 CONT'D.

7. A valence shell can hold up to 18 electrons.

   A. true
   B. false

8. A battery is an example of an AC power source.

   A. true
   B. false

9. Electrons that are released easily from their orbits are known as "free" electrons.

   A. true
   B. false

10. An electron is about 1840 times lighter than a proton.

   A. true
   B. false

EXAM A 1.4

ANSWER KEY

1. A
2. B
3. D
4. D
5. C
6. A
7. B
8. B
9. A
10. A

ELECTRONICS

ANALYZING DC CIRCUITS

A 2: VOLTAGE, CURRENT & RESISTANCE

TASK: Identify voltage, current and resistance.

PURPOSE: In almost every circuit there are three factors that are important to identify and understand. They are voltage, current and resistance. Each factor is dependent upon the other. In this learning guide you will be introduced to the basic characteristics of voltage, current and resistance.

OBJECTIVE: Given access to all necessary tools and equipment, you will identify and measure voltage, current and resistance. To master this task, you must score 80% on a written exam and performance checklist.

ESTIMATED CLASS TIME: 4 HOURS

VOLTAGE, CURRENT AND RESISTANCE

LEARNING STEPS

A 2

READ:	Information on "Voltage, Current and Resistance" in Information Sheet A 2.1.
READ	Information on "Voltage, Current and Resistance" from the following resource list.
VIEW:	Audio/Visual material on "Voltage, Current and Resistance." Contact your instructor.
COMPLETE:	Activity Sheet A 2.2 on "Voltage, Current and Resistance."
COMPLETE:	Activity Sheet A 2.3 on "Voltage, Current and Resistance Problems."
COMPLETE:	Lab Performance on "Voltage, Current and Resistance." Contact your instructor for this lab.
COMPLETE:	Performance Checklist A 2.4. Contact your instructor.
REVIEW:	All material covered in this learning guide and information presented by your instructor.
COMPLETE:	Written Exam A 2.5. Contact your instructor.

VOLTAGE, CURRENT AND RESISTANCE

RESOURCES

A 2

1. BASIC ELECTRICITY AND CIRCUIT CONCEPTS: VOL. 1, DC CIRCUITS, Oliva and Dale (Radio Shack: Texas Instrument Learning Center, 1979), 4th Edition. Chapter 1.

2. DC ELECTRONICS (Heathkit Educational Systems, 1984). Units I & II.

3. BASIC ELECTRONICS, Grob (McGraw-Hill, 1984). Chapter 1.

4. INTRODUCTION TO ELECTRICITY AND ELECTRONICS, Bell & Howell Schools (DeVry Institute of Technology, 1984). Chapter 1001.

5. INTRODUCTION TO INDUSTRIAL ELECTRICITY-ELECTRONICS (Oklahoma Trade and Industrial Education).

6. ELECTRONICS: PRINCIPLES AND APPLICATIONS, Badrkhan and Larky (South Western Pub.). Chapter 1.

7. ELECTRICITY ONE-SEVEN, Mileaf (Hayden). Chapter 1.

8. ELECTRONIC COMMUNICATION, Schrader (McGraw-Hill Pub. Co.). 5th Ed. Chapter 1.

INFORMATION SHEET

A 2.1

VOLTAGE, CURRENT AND RESISTANCE

In learning guide #1, "Identify Sources of Electricity", you learned some basic concepts about electricity. You were introduced to the atom and to electricity, the movement of electrons from one orbit to another. Also, you were introduced to the laws of electrostatics: "like charges repel; unlike charges attract." Sources of electricity and devices that deliver that electricity were discussed. In this learning guide you will be introduced to three factors that are an important part of electricity: voltage, current, and resistance.

VOLTAGE

Remember, it takes 6.25 x 10^{18} electrons to equal 1 Coulomb. It's easier to think in terms of 1 Coulomb (or 1 C) rather than try to count the billions of electrons that are in a circuit. We can also think of 1 C as a "potential" that can be applied to a circuit. Two Coulombs of different values, connected together by a conductor, are called "a difference of potential" or voltage (V). A battery, as an example, relies on the chemical action which occurs between two different metals called electrodes. As the chemicals react, the electrodes accumulate opposite charges. If a conductor is connected between the two electrodes, electrons will leave the negative terminal and flow through the conductor to the positive terminal.

Voltage is the "PUSH" or pressure that makes the electrons move in a circuit. Another term used to describe this "PUSH" is electromotive force (EMF). All three terms refer to the same action in a circuit.

VOLTAGE= POTENTIAL DIFFERENCE = ELECTROMOTIVE FORCE

A voltage always involves a high potential and a low potential. In order to produce a voltage, THERE MUST BE DIFFERENCE OF POTENTIAL BETWEEN 2 POINTS. (usually we call these two points terminals.) In a normal battery there is a positive (+) terminal and a negative (-) terminal. See Figure A 2.1-1.

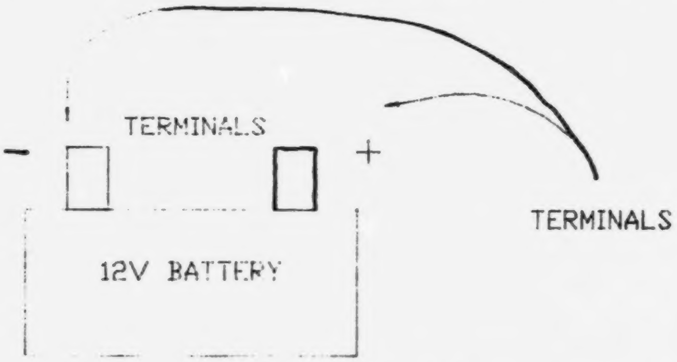


Figure A 2.1-1

"Positive" or "negative" voltages can be produced by establishing various values for the two points. For instance, in the following example the difference of potential is 2 Coulombs in each a), b), and c).
See Figure A 2.1-2.

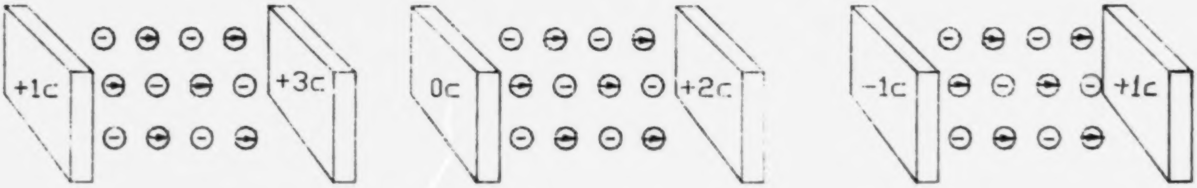


Figure A 2.1-2

Often it is convenient to pick one point and use it as a "reference" point. Voltages are then measured at other points with respect to that reference point. In electronic equipment, the metal case or chassis is considered the reference point. The chassis is said to be at "ground" potential. A reference point connected to the earth is called "earth" ground.

CURRENT

If 1 Coulomb of electrons passes by a point in one second, it is called 1 ampere or amp. The abbreviation for ampere is A. An ampere is probably the largest unit for current you will run into everyday, but when working with electronic equipment, sometimes a smaller unit is needed. A milliamp is 1/1000 of an ampere, and 1/1,000,000 of an ampere is a microampere.

Current is represented by the letter "I," which represents "Intensity." Again, its units are measured in amperes, milliamperes, or microamperes.

There are two different ways we can describe current flow: conventional and electron. Conventional current flow was first discovered by Ben Franklin. He thought the current carriers in a conductor were positive charges. Therefore, he believed that the positive current carriers flowed from a high potential to a low potential. Since Franklin's time, electrons have been found to be the the current carriers instead of the positive charges. Because it is known that the negative electrons actually move through conductors, the electron flow theory is in wide use today. But, since current has no polarity, each theory has its merits.

RESISTANCE

Resistance can be describe as the "opposition to current flow." The component that is used to offer resistance in a circuit is called a resistor. A resistor is used in a circuit to "drop" voltages and control the current flow. Its units are measured in ohms, and the symbol is Ω . One thousand ohms can be abbreviated 1kΩ . "k" stands for x1000. One million ohms can be written 1MegΩ or 1MΩ.

Resistors come in many shapes and sizes. Here are some examples:

1) fixed resistor---the value of the resistor is set permanently.
2) variable resistor---the value can be changed from one value to another as in a/or in a potentiometer rheostat.
3) adjustable resistor---the value can be changed by moving a fixed terminal along the resistor.

RESISTANCE CHARACTERISTICS

Resistors are built to withstand the effects of heat. When heat is present in a circuit, there is a relationship of voltage, current and resistance which is known as "power."

Power can be measured in watts, kilowatts (1000 watts), and Megawatts (1,000,000 watts). Learning guide #5 will cover power in more detail.

Resistors are also measured according to how much heat they can dissipate--or in other words they are given a wattage. Resistors limit the amount of current in circuit.

There several factors that determine resistance. They are:

1) the composition of the resistive material.
2) the cross sectional area of the material.
3) the length of the material.
4) the temperature.

VOLTAGE, CURRENT AND RESISTANCE

A relationship between voltage, current and resistance can be expressed in a formula called Ohm's Law. That is:

$$E = I \times R$$

"E" represents potential difference, "I" represents current, and "R" represents resistance. Simply stated, Ohm's Law says that if the voltage in a circuit is increased while the resistance is held constant, the current will increase in direct proportion to the applied voltage.

You've been introduced to some facts about voltage, current and resistance in this learning guide. To understand these concepts in more detail, follow the "Learning Steps" portion of this guide.

ACTIVITY SHEET

A 2.2

VOLTAGE, CURRENT & RESISTANCE

DIRECTIONS: Complete each question. DO NOT CONTINUE with any portion of this guide until the Activity Sheet has been completed. If you need any help, see your instructor.

1) Define voltage:

2) What are 3 terms that refer to the "PUSH" applied to the electrons in a circuit?

3) Define "resistance":

4) Name 3 different examples of resistors:
   1)
   2)
   3)

5) Discuss the difference between conventional current flow and electron flow.

ACTIVITY SHEET A 2.2 CONT'D.

6) What is meant by the term "chassis ground"?

7) Define current:

8) Fill in the blanks.

A) 1500Ω = ___________kΩ
B) 750 mA = ___________A
C) .5 kv = ___________v

9) List 4 factors that determine resistance:
   1)
   2)
   3)
   4)

10) What algebraic formula is used to describe the relationship between voltage, current, and resistance?

ACTIVITY SHEET A 2.2

ANSWER SHEET

1) The "push" or pressure that makes electrons move in a circuit.

2) 1)voltage 2)potential difference 3)electromotive force

3) Resistance is the "opposition to electron flow."

4) 1)fixed 2)variable 3)adjustable

5) Conventional-positive charges are the current carries in a circuit, and current flows from a positive potential to negative potential. Electrons are the current carriers. Current flows from (-) to (+) potential.

6) A common reference point is chosen when working with electronic equipment. This reference point is usually the (-) terminal of the power source. The chassis or frame is usually used as the conductor for current to return to the source.

7) The flow of electrons.

8) 1) 1.5 kΩ
    2) .750 A
    3) 500 v

9) 1) cross-sectional area
    2) length of the resistor
    3) material used in construction of the resistor
    4) temperature

10) Ohm's Law, $E = I \times R$; or any variation of Ohm's Law $I=\frac{E}{R}$;

or $R=\frac{E}{I}$

ACTIVITY SHEET

A 2.3

VOLTAGE, CURRENT AND RESISTANCE PROBLEMS

1. Briefly define the following terms. Also give each term, symbol and unit of measure.

    a) charge
    b) current
    c) potential difference
    d) resistance

2. A charged body has an excess of 2.49×10^{19} electrons. What is the stored charge in C?

3. A charged body has a deficit of 1.87×10^{16} electrons. What is the stored charge in C?

4. If 0.900 C of charge passes a point in a circuit in 1 1/2 minutes, what is the value of the electrical current?

5. If the charge through a certain circuit is 5 amps., how long will it take to transport 0.255 C of charge?

6. The current flowing through the resistor in Figure A 2.3-1 is 125mA. What must be the value of the resistance if the EMF of the battery is (a) 1.00 volt, (b) 10.0 volts, (c) 50.0 volts, and (d) 800 volts?

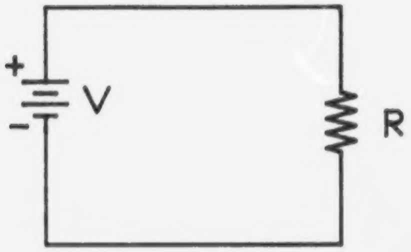


Figure A 2.3-1

ACTIVITY SHEET A 2.3 CONT'D.

7. The battery in Figure A 2.3-1 has an EMF of 12 V. What current will flow in the circuit if the resistor has a value of

   (a) 5 ohms
   (b) 240 ohms
   (c) 12 K ohms
   (d) 2M ohms?

8. The resistor in Figure A 2.3-1 has a value of 1 Kilo ohm. What must be the EMF of the battery to provide a current of

   (a) 1.00 mA
   (b) 20.0 mA
   (c) 500 mA
   (d) 2.00 A?

9. The battery in Figure A 2.3-2 has an EMF of 470 volts. What are the minimum and maximum values of current if the 470 K ohm resistor has a +/- 50% tolerance?

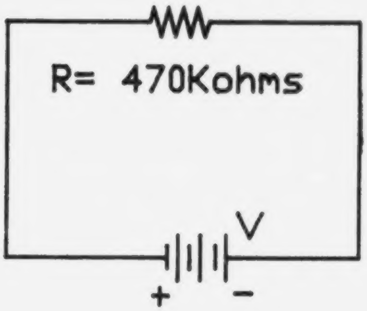


Figure A 2.3-2

10. If the bulb of Figure A 2.3-3 draws a current of 75 mA, what must be the resistance of the bulb?

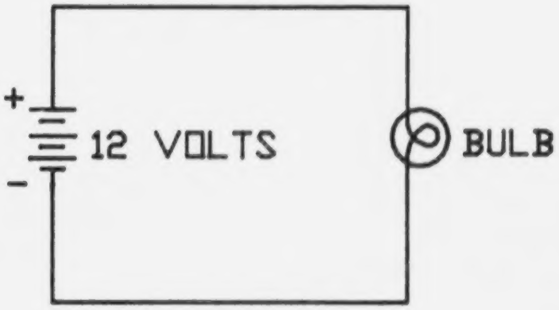


Figure A 2.3-3

ACTIVITY A 2.3

ANSWER SHEET

1. (a) Coulombs-Q
   (b) Amperes-I
   (c) Volts-V
   (d) Ohms-R

2. $Q = -1.6 \times 10^{-19} \times 2.49 \times 10^{19} = -3.98C$

3. $Q = 1.6 \times 10^{-19} \times 1.87 \times 10^{16} = 2.99mC$

4. I = Q/t = 0.900C/90 sec = 10 mA

5. t = Q/I = 0.255/5.00 = 51 m Sec

6. R = V/I

   (a) 1.00/0.125 = 8 ohms
   (b) 10/0.125 = 80 ohms
   (c) 50/0.125 = 400 ohms
   (d) 800/0.125 = 6,400 ohms

7. I = V/R

   (a) 12/5 = 2.40 A
   (b) 12/240 = 50.0 mA
   (c) 12/12 K ohms = 1.00 mA
   (d) 12/12 M ohms = 6.00 microA

8. V = I * R

   (a) 1 mA x 1 K ohm = 1.00 V
   (b) 20 mA x 1 K ohm = 20.0 V
   (c) 500 mA x 1 K ohm = 500 V
   (d) 2A x 1 K ohm = 2,000 V

9. 5% of 470 K ohms = 24 K ohms, R max = 494 K ohms, R min = 446 K ohms, I min = 470V/494K = 0.951 mA, I max = 470V/446 K ohms = 1.05 mA

10. R = V/I = 12/75 mA = 16050

PROGRAM: ELECTRONICS

TASK: VOLTAGE, CURRENT & RESISTANCE

TASK # A 2.4

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE __________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT __________

TERMINAL PERFORMANCE OBJECTIVE:

IDENTIFY VOLTAGE, CURRENT AND RESISTANCE.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance, within 30 minutes and must score at least 6 out of 7 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

VOLTAGE, CURRENT, RESISTANCE

A 2.4

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the circuit wired according to the schematic?	Y N
*2.	Does the circuit function properly?	Y N
*3.	Was necessary data recorded?	Y N
4.	Was the correct equipment used?	Y N
*5.	Was the equipment used correctly?	Y N
6.	Were safety precautions followed?	Y N
7.	Was the equipment returned to proper storage area?	Y N

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

STUDENT'S SCORE ____

VOLTAGE, CURRENT & RESISTANCE

EXAM

A 2.5

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Voltage, Current and Resistance. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer a minimum of 8 out of 10 items correctly, 80%.

VOLTAGE, CURRENT, AND RESISTANCE

EXAM

A 2.5

1. (Electron Theory) Electrons tend to move toward a more positive potential in a circuit?

   A. true
   B. false

2. If one coulomb of charge passes a point in one second, then there is 1 ampere of current flowing in the circuit.

   A. true
   B. false

3. _____ is the "opposition to current flow."

   A. voltage
   B. resistance
   C. current
   D. wattage

4. A DC voltage source has terminals with different charges.

   A. true
   B. false

5. To produce current in a circuit, an electromotive force is connected to a load.

   A. true
   B. false

6. There is ____________mA of current flow when there is a zero potential difference.

   A. .10
   B. 5
   C. 10
   D. 0

7. 500mA is the same as _____________ amperes.

   A. 5,000
   B. 5,000,000
   C. .5
   D. .005

8. A resistor that has a constant value is called a(n) ____________ resistor.

   A. variable
   B. adjustable
   C. common
   D. fixed

9. Which of the terms below does not determine resistance?

   A. cross sectional area
   B. length
   C. temperature
   D. conductance

10. Current is the flow of electrons in a circuit and is measured in ______________.

   A. amperes
   B. volts
   C. ohms
   D. watts

EXAM A 2.5

ANSWER KEY

1. A
2. A
3. B
4. A
5. A
6. D
7. C
8. D
9. D
10. A

ELECTRONICS

ANALYZING DC CIRCUITS

A 3: CONDUCTORS AND INSULATORS

TASK:	Compute/measure resistance and conductance of conductors and insulators.
PURPOSE:	It may be important to know circuit parameters such as the resistance of conductors or the conductance of of insulators to determine current flow. In this learning guide, you will become familiar with conductors and insulators, and the resistance or conductance they offer in a circuit.
OBJECTIVE:	Given access to all necessary tools and equipment, you will compute/measure conductance and resistance of conductors and insulators. To master this task, you must score 80% on a written exam and performance checklist.

ESTIMATED CLASS TIME: 6 HOURS

CONDUCTORS AND INSULATORS

LEARNING STEPS

A 3

READ:	Information on "Conductors and Insulators" in Information Sheet A 3.1.
READ:	Information on conductors and insulators from the following resource list. See your instructor.
VIEW:	Audio/visual material on conductors and insulators. Contact your instructor.
COMPLETE:	Activity sheet A 3.2 on "Conductors and Insulators".
COMPLETE:	Activity Sheet A 3.3 on "Conductor and Resistance Problems."
COMPLETE:	Lab performance on conductors and insulators. Contact your instructor for this lab.
COMPLETE:	Performance Checklist A 3.4. Contact your instructor.
REVIEW:	All material covered in this learning guide and information presented by your instructor.
COMPLETE:	Written exam A 3.5. Contact your instructor.

CONDUCTORS AND INSULATORS

RESOURCES

A 3

1. BASIC ELECTRICITY AND CIRCUIT CONCEPTS: VOL. 1, DC CIRCUITS, Oliva and Dale (Radio Shack: Texas Instrument Learning Center, 1979), 4th Edition. Chapter 1.

2. DC ELECTRONICS (Heathkit Educational Systems, 1984). Units I & II.

3. BASIC ELECTRONICS, Grob (McGraw-Hill, 1984). Chapter 1.

4. INTRODUCTION TO ELECTRICITY AND ELECTRONICS, Bell & Howell Schools (DeVry Institute of Technology, 1984). Chapter 1001.

5. INTRODUCTION TO INDUSTRIAL ELECTRICITY-ELECTRONICS (Oklahoma Trade and Industrial Education).

6. ELECTRONICS: PRINCIPLES AND APPLICATIONS, Badrkhan and Larky (South Western Pub.). Chapter 1.

7. ELECTRICITY ONE-SEVEN, Mileaf (Hayden). Chapter 1.

8. ELECTRONIC COMMUNICATION, Schrader (McGraw-Hill Pub. Co.). 5th Ed. Chapter 1.

INFORMATION SHEET

A 3.1

CONDUCTORS AND INSULATORS

If resistance is the "opposition to current flow," then conductance has low resistance and has many free electrons. Everything in nature contains some resistance, but it is those elements that offer little opposition to electron flow that are considered to be good conductors.

Copper is used extensively in electrical wiring, electrical equipment, and electronics. It is given the reference value of 1. So, all conductors are compared to copper as to their effectiveness as a conductor. Silver's value is less than 1 since it is better conductor than copper. Gold is slightly higher than 1.

Good conductors typically have only one electron in their valence ring. Since the lone electron is held loosely in its orbit, it wants to find a new orbit to make the element more stable.

Conductance can be expressed: $G = 1/R$. G stands for conductance and is measured in "ohm's" or siemens (s). A circuit that offers 5 Ω of resistance has .2 ohm's of conductance. The symbol for G is ℧ .

DEFINITION: Conductor - materials through which electrons flow easily.

Heat plays an important role in circuits. If impurities are present in a conductor, they will decrease the conductivity. As an example, corrosion on wires and terminals greatly decrease conductivity and increase resistance.

Insulators are materials with very few free electrons. Sometimes they are called "non-conductors." A very good insulator will have 7 electrons in its valence ring, and needs one more electron to make the element stable.

Moderate amounts of heat have little effect on good insulators; however, prolonged exposure to heat will cause many insulating materials to harden, become brittle, crack, peel, and often become semiconductors.

Some examples of insulators are: porcelain, glass, nylon.

DEFINITION: Insulator - material restricting electron flow.

Conductance and non-conductance are present in all circuits. A conductor, whether it be a copper wire, aluminum heat sink, or gold contact, all allow current to flow. But insulators offer a high resistance in a circuit.

Conductance formula:

$$G = 1/R$$

Solid copper wire can be used as conductor only if the conductor requires little bending; it will break if flexed too often. Many times standard copper wire is used as hookup wire. It does not break as easily as solid wire.

The wire's resistance varies (1) with the material, (2) inversely to its circular mil area, (3) directly with its length, (4) and with temperature changes.

Printed etched circuit boards offer an alternative to wires that are used in electronic equipment. Copper tracings can be formed on one or both sides of a fiberglass board.

In this learning guide, you have been introduced to some concepts regarding conductors and insulators. The "learning steps" portion of this guide will provide you with additional information on conductors and insulators.

ACTIVITY SHEET

A 3.2

CONDUCTORS AND INSULATORS

DIRECTIONS: Complete each question. DO NOT CONTINUE with any portion of this guide until the Activity Sheet has been completed. If you need any help, see your instructor.

1. What is a conductor?

2. List 3 very good conductors:

   a.
   b.
   c.

3. Give the formula for finding conductance.

4. If a circuit has a resistance of 20Ω, what is its conductance?

5. How does heat effect a conductor?

6. If there are impurities in the conductor, how does this effect an insulator?

7. List 3 materials used in insulators.

   a.
   b.
   c.

ACTIVITY SHEET A 3.2 CONT'D.

8. In what type of circuit would finding conductance be most often be used?

9. What advantage does stranded wire have over solid wire?

10. List four ways in which a wire's resistance varies.

    a.
    b.
    c.
    d.

ACTIVITY SHEET A 3.2

ANSWER SHEET

1. Material that allows electrons to flow easily.
2. Silver, copper, gold, aluminum
3. G = 1/R
4. .05 mhos or .05 ℧
5. Heat increases resistance of the conductor.
6. Impurities assist the flow of electrons in an insulator.
7. Porcelain, glass, nylon, rubber
8. Parallel
9. The wire can bend easier (more flexible).
10. Resistance of a wire varies:
    a. with the material
    b. inversely as its circular mil area
    c. directly with its length
    d. with temperature changes

ACTIVITY SHEET

A 3.3

CONDUCTANCE AND RESISTANCE PROBLEMS

1. What length of nichrome wire having a diameter of 10 mils must be used to obtain a resistance of 47Ω .

2. Calculate the resistance of 1000 ft. of AWG no. 20 copper wire.

3. Calculate the resistance of 100 ft. of AWG no. 13 copper wire.

4. What is the minimum size copper wire that is safe to connect a 3Ω load to a 120 volt source?

5. What are the upper and lower limits of a 1.5 K ohm, 10% resistor?

6. The resistance needed for a circuit is calculated as 520 ohms. What is the closest standard 10% copper wire at 0° C?

7. What is the resistance of 1000 ft. of AWG no. 10 copper wire at 0° C?

8. What must be the temperature coefficient of a thermistor whose resistance doubles when the temperature is decreased from 20° to 0° C?

9. What is the conductance G of the following resistors?

   a. 500 ohms
   b. 1 M ohms
   c. 2.2 K ohms

10. What voltage must be applied across a resistor having a conductance of 4 mS in order to cause a current of 16 mA? What is the resistance of the resistor?

ACTIVITY SHEET A 3.3

ANSWER SHEET

1. $L = R \times d^2/L = 47 \times 10^2/660 = 5$ ft.

2. 1000 ft. of AWG #10 1 ohm; 1000 ft. of AWG #20 10

3. 1000 ft. of AWG #10 1 ohm; 100 ft. of AWG #10 0.1 ohm
   ; 100 ft. of AWG #13 0.2 ohm

4. Current capacity table: AWG #10 -> 40A,
   Since $I = V/R = 120/3 = 40A$

5. 10% of 1. 5 K ohms = 150 ohms; Rmax = 1.5K + 150 = 1.65 K ohm
   Rmin = 1.5K - 150 = 1.35 K ohm

6. 560

7. $R = R_{20} [1 + \alpha(T-20)] = 1.0 [1 + 0.00393 (0 - 20)] =$

   $[1 - 0.0786] = 0.921$ ohm

8. $R = R_{20} [1 + \alpha(T-20)] =$ so, $2 R_{20} = R_{20} [1 + \alpha (0 -20)]$,

   $2 = (1 - 20\alpha) \quad = -1/20 = -0.05$

9. $G = 1/R =$

   (a) 1/500 = 2mS
   (b) G = 1/1m ohm = 1 mico S
   (c) G = 1/2.2K ohm = 0.454mS

10. $V = I/G = 16$ mA/4mS = 4.0 volts

    $R = 1/G = 1/4$ mS = 250 ohms

PROGRAM: ELECTRONICS

TASK: CONDUCTORS & INSULATORS

TASK #: A 3.4

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ____________

TERMINAL PERFORMANCE OBJECTIVE:

COMPUTE/MEASURE RESISTANCE AND CONDUCTANCE OF CONDUCTORS AND INSULATORS.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

CONDUCTORS & INSULATORS

A 3.4

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the circuit wired according to the schematic?	Y N
* 2.	Does the circuit function properly?	Y N
3.	Was necessary data recorded?	Y N
* 4.	Was the correct equipment used?	Y N
* 5.	Was the equipment used correctly?	Y N
6.	Were safety precautions followed?	Y N
7.	Was the equipment returned to proper storage area?	Y N

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

STUDENT'S SCORE ____

CONDUCTORS AND INSULATORS

EXAM

A 3.5

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Conductors and Insulators. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer a minimum of 8 out of 10 items correctly, 80%.

CONDUCTORS AND INSULATORS

EXAM

A 3.5

1. A very good insulator may have ________________ electrons in its valence ring.

   a. 0
   b. 1
   c. 3
   d. 7

2. A(n) ________________ offers little resistance to electron flow.

   a. atom
   b. conductor
   c. insulator
   d. compound

3. "Ohms" means that the majority of current travels thorough the center of a conductor.

   a. true
   b. false

4. Which of the following is the best conductor?

   a. aluminum
   b. gold
   c. silver
   d. copper

5. Printed circuit board wiring is almost never used in electronic equipment.

   a. true
   b. false

6. If one branch of a parallel circuit offers .01 ohms, how much resistance is that?

   a. 100 Ω
   b. 1 kΩ
   c. 100 kΩ
   d. 10 Ω

7. Corrosion on wires and terminals greatly decreases conductivity?

   a. true
   b. false

EXAM A 3.5 CONT'D.

8. __________ is rated at 1.00 for conductivity?

   a. gold
   b. silver
   c. mercury
   d. copper

9. The resistance of a wire varies directly with its circumference.

   a. true
   b. false

10. Stranded wire is more flexible than solid wire.

   a. true
   b. false

EXAM A 3.5

ANSWER KEY

1. D
2. B
3. B
4. C
5. B
6. A
7. A
8. D
9. B
10. A

ELECTRONICS

ANALYZING DC CIRCUITS

A 4: READ AND INTERPRET COLOR CODES

TASK: Read and interpret color codes.

PURPOSE: Being able to read and interpret color codes is an essential part in understanding electronics components. Color codes give specific information about component like resistors. In this learning guide, you will learn to read and interpret a resistor color code.

OBJECTIVE: Given access to all necessary tools and equipment, you will read and interpret color codes. To master this task, you must score 80% on a written exam and performance checklist.

ESTIMATED CLASS TIME: 4 HOURS

READ AND INTERPRET COLOR CODES

LEARNING STEPS

A 4

READ:	Information Sheet A 4.1 , "Color Codes."
READ:	Information on color codes from the following resource list. See your instructor.
REVIEW:	Audio/Visual material on color codes. Contact your instructor.
COMPLETE:	Activity Sheet A 4.2 on color codes.
COMPLETE:	Lab performance on color codes. Contact your instructor for this lab.
COMPLETE:	Performance Checklist A 4.3. Contact your instructor.
REVIEW:	All material covered in this learning guide and information presented by your instructor.
COMPLETE:	Written Exam A 4.4. Contact your instructor.

READ AND INTERPRET COLOR CODES

RESOURCES

A 4

1. BASIC ELECTRICITY AND CIRCUIT CONCEPTS: VOL. 1, DC CIRCUITS, Oliva and Dale (Radio Shack: Texas Instrument Learning Center, 1979), 4th Edition. Chapter 1.
2. DC ELECTRONICS (Heathkit Educational Systems, 1984). Units I & II.
3. BASIC ELECTRONICS, Grob (McGraw-Hill, 1984). Chapter 1.
4. INTRODUCTION TO ELECTRICITY AND ELECTRONICS, Bell & Howell Schools (DeVry Institute of Technology, 1984). Chapter 1001.
5. INTRODUCTION TO INDUSTRIAL ELECTRICITY-ELECTRONICS (Oklahoma Trade and Industrial Education).
6. ELECTRONICS: PRINCIPLES AND APPLICATIONS, Badrkhan and Larky (South Western Pub.). Chapter 1.
7. ELECTRICITY ONE-SEVEN, Mileaf (Hayden). Chapter 1.
8. ELECTRONIC COMMUNICATION, Schrader (McGraw-Hill Pub. Co.). 5th Ed. Chapter 1.

INFORMATION SHEET

A 4.1

COLOR CODES

Since resistors are one of the components that determine the current in a circuit, it is important to know how to select the correct resistors.

The resistor color code is one of the most important codes that must be learned in electronics, because it gives specific information on the resistances that are in a circuit. It is also used to choose various resistors for a specific need.

Standard resistors will usually have four brands colored around them. Refer to Figure A 4.1-1.

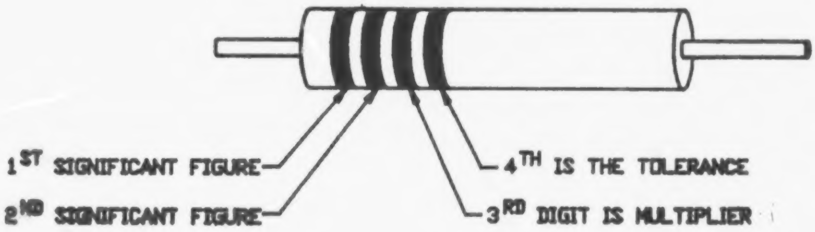


Figure A 4.1-1

In the figure, each band represents a specific value. the first band (which is the closest to an end of the resistor) is called the 1st significant figure or digit. The second band is referred to as the 2nd significant figure or digit. Both of these values (the 1st and 2nd significant figures) will be multiplied by the third band - the multiplier band. Finally, the fourth band is the tolerance band. This band will give the "range" at which the resistor will be rated. Each band may take a different color and, therefore, a different value. You can assign each band the correct value by reading the color code and applying the values from Figure A 4.1-2. In Figure A 4.1-1 a color code is given.

INFORMATION SHEET A 4.1 CONT'D.

FIGURE A 4.1-2

COLOR	BAND 1 1st Digit	BAND 2 2nd Digit	BAND 3 Multiplier 3rd Digit	BAND 4 Tolerance (%)	BAND 5 Reliability
Black	0	0	1		
Brown	1	1	10		(M) 1.0
Red	2	2	100		(P) 0.1
Orange	3	3	1,000		(R) 0.01
Yellow	4	4	10,000		(S) 0.001
Green	5	5	100,000		
Blue	6	6	1,000,000		
Violet	7	7	10,000,000		
Gray	8	8	100,000		
White	9	9	1,000,000,000		
Gold			.1	+/- 5%	
Silver			.01	+/- 10%	
No Band				+/- 20%	

Notice, the fifth band in Figure A 4.1-2. This band is for temperature specifications and circuit reliability. Not all resistors have five bands-most have four. Another interesting point about the table is gold and silver are used as multipliers for the third band. If a resistor has a gold or silver color for its third band, it is called a "precision" resistor.

To see how to use the color code, look at Figure A 4.1-3.

INFORMATION SHEET A 4.1 CONT'D.

If the assigned values for each bond in the examples were given, then their ohm value can be found.

FIGURE A 4.1-3

	BANDS				OHMS VALUE
	1st	2nd	3rd	4th	ANSWER
Example 1	Orange 3	Orange 3	Gold x .1	Gold 5%	3.3
Example 2	Red 2	Red 2	Silver x .01	Gold 5%	.22
Example 3	Yellow 4	Violet 7	Yellow x 10,000	Silver 10%	470,000 or 470 K

To learn how the color code works requires some practice. So, continue on with Learning Steps in this learning guide.

ACTIVITY SHEET

A 4.2

COLOR CODES

DIRECTIONS: Complete each question. DO NOT CONTINUE with any portion of this guide until the Activity Sheet has been completed. If you need any help, see your instructor. Refer to Figure A 4.2-1. Give the ohmic value and tolerance for each question.

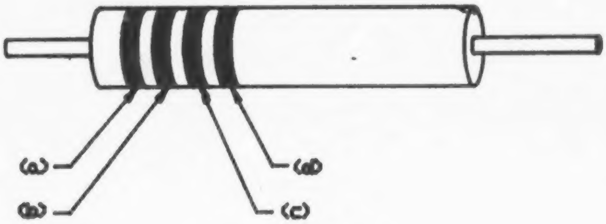


Figure 4.2-1

1. (a) red (b) orange (c) brown (d) gold

______________ Ω

2. (a) blue (b) gray (c) red (d) no band

______________ Ω

3. (a) violet (b) green (c) brown (d) gold

______________ Ω

4. (a) green (b) green (c) gold (d) gold

______________ Ω

5. (a) orange (b) black (c) orange (d) gold

______________ Ω

6. (a) orange (b) white (c) green (d) silver

______________ Ω

7. (a) red (b) black (c) brown (d) silver

______________ Ω

ACTIVITY SHEET A 4.2 CONT'D.

8. (a) brown (b) red (c) yellow (d) no band

________________ Ω

9. (a) blue (b) black (c) black (d) gold

________________ Ω

10. (a) brown (b) green (c) red (d) silver

________________ Ω

ACTIVITY SHEET A 4.2

ANSWER SHEET

1. 230 Ω 5%
2. 6800 Ω 20%
3. 750 Ω 5%
4. 5.5 Ω 5%
5. 30,000 Ω 5%
6. 3,900,000 Ω 10%
7. 200 Ω 10%
8. 120,000 Ω 20%
9. 60 Ω 5%
10. 1500 Ω 10%

PROGRAM: ELECTRONICS

TASK: READ AND INTERPRET COLOR CODES

TASK #: A 4.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

READ AND INTERPRET COLOR CODES.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

COLOR CODES

A 4.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the circuit wired according to the schematic?	Y N
2.	Does the circuit function properly?	Y N
*3.	Was necessary data recorded?	Y N
4.	Was the correct equipment used?	Y N
*5.	Was the equipment used correctly?	Y N
6.	Were safety precautions followed?	Y N
*7.	Was the equipment returned to proper storage area?	Y N

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

STUDENT'S SCORE ____

COLOR CODES

EXAM

A 4.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Color Codes. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer a minimum of 8 out of 10 items correctly, 80%.

COLOR CODES

EXAM

A 4.4

1. Given the color codes in Figure A 4.1-1, select the correct resistance.

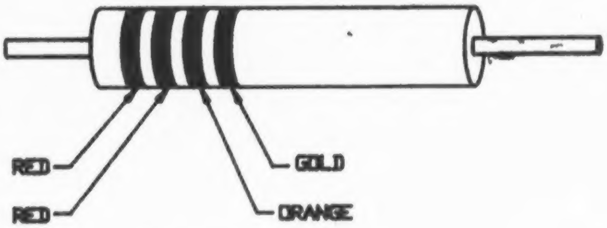


Figure A 4.1-1

a. 23 Ω 10%
b. 220 Ω 5%
c. 22000 Ω 5%
d. 2.2 Ω 5%

2. Given the color codes in Figure A 4.4-2, select the correct resistance.

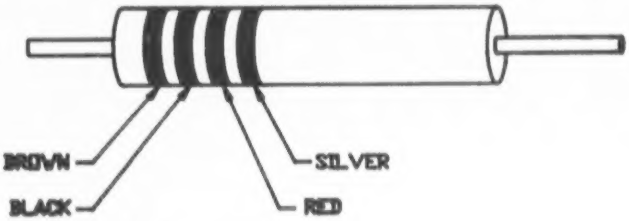


Figure A 4.4-2

a. 100 Ω 10%
b. 1000 Ω 10%
c. 1000 Ω 5%
d. 10000 Ω 10%

3. The third band is called the tolerance band.

a. true
b. false

4. If the band closest to the end of a resistor is yellow, it stands for what numerical value?

a. 4
b. 7
c. 0
d. no band

5. A carbon resistor with brown, gray, orange, and gold bands has a resistance of:

   a. 1800 Ω 10%
   b. 18,000 Ω 10%
   c. 18,000,000 Ω 5%
   d. 18,000.0 Ω 5%

6. A resistor is 1000Ω . What colors would be present on the resistor?

   a. brown, blue, yellow
   b. brown, black, red
   c. brown, red, violet
   d. brown, brown, brown

7. The fifth band is always on a carbon composition resistor.

   a. true
   b. false

8. If the third band is silver, multiply the first two significant digits by .01.

   a. true
   b. false

9. The color gray represents the number "9" in the color code.

   a. true
   b. false

10. The fourth band will give the range of the resistor (or tolerance).

   a. true
   b. false

EXAM A 4.4

ANSWER KEY

1. C
2. C
3. B
4. A
5. D
6. B
7. B
8. A
9. B
10. A

ELECTRONICS

ANALYZING DC CIRCUITS

A 5: OHM'S LAW

TASK:	Apply Ohm's Law.
PURPOSE:	Ohm's Law is a relationship between voltage, current and resistance. It can be used to find unknown values in a circuit. In this Learning Guide you will explore some of the fundamentals of Ohm's Law.
OBJECTIVE:	Given access to all necessary tools and equipment, you will apply Ohm's Law in a DC circuit. To master this task, you must score 80% on a written exam and performance checklist.

ESTIMATED CLASS TIME: 3 HOURS

OHM'S LAW

LEARNING STEPS

A 5

READ: Information Sheet A 5.1 on "Ohm's Law."

READ: Information on Ohm's Law in one or more of the resources listed below. See your instructor.

VIEW: Audio/visual material on Ohm's Law. Contact your instructor.

COMPLETE: Activity Sheet A 5.2 on "Ohm's Law."

COMPLETE: Activity Sheet A 5.3 on "Ohm's Law Problems."

COMPLETE: Lab Performance on Ohm's Law. Contact your instructor for this lab.

COMPLETE: Performance Checklist A 5.4. Contact your instructor.

REVIEW: All material covered in this learning guide and information presented by your instructor.

COMPLETE: Written Exam A 5.5. Contact your instructor.

OHM'S LAW

RESOURCES

A 5

1. BASIC ELECTRICITY AND CIRCUIT CONCEPTS: VOL. 1, DC CIRCUITS, Oliva and Dale (Radio Shack: Texas Instrument Learning Center, 1979), 4th Edition. Chapter 1.
2. DC ELECTRONICS (Heathkit Educational Systems, 1984). Units I & II.
3. BASIC ELECTRONICS, Grob (McGraw-Hill, 1984). Chapter 1.
4. INTRODUCTION TO ELECTRICITY AND ELECTRONICS, Bell & Howell Schools (DeVry Institute of Technology, 1984). Chapter 1001.
5. INTRODUCTION TO INDUSTRIAL ELECTRICITY-ELECTRONICS (Oklahoma Trade and Industrial Education).
6. ELECTRONICS: PRINCIPLES AND APPLICATIONS, Badrkhan and Larky (South Western Pub.). Chapter 1.
7. ELECTRICITY ONE-SEVEN, Mileaf (Hayden). Chapter 1.
8. ELECTRONIC COMMUNICATION, Schrader (McGraw-Hill Pub. Co.). 5th Ed. Chapter 1.

INFORMATION SHEET

A 5.1

OHM'S LAW

Ohm's Law defines the way in which current, voltage, and resistance are related. Ohm's Law states that current is directly proportional to voltage and inversely proportional to resistance.

Algebraically, Ohm's Law can be stated: $E = I \times R$, where E = voltage, I = current, and R = resistance. Variations of Ohm's Law are: $I = \frac{E}{R}$ and $R = \frac{E}{I}$.

In order to apply Ohm's Law to a circuit, two of three variables must be known. The third variable can then be found.

Many times Ohm's Law is used to solve for "total" values in a circuit, such as E_{TOTAL}, I_{TOTAL}, AND R_{TOTAL}. But, it also is used to find individual values of E, I, and R in the circuit, i.e., voltage drops across various resistors, current through various parallel branches, and resistances of individual resistors.

Useful in implementing Ohm's Law is the wheel diagram. This gives the troubleshooter a quick took for finding the corrrect formula to use in a circuit. See Figure A 5.1-1.

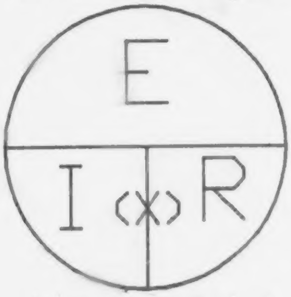


Figure A 5.1-1

If the user covers the variable that is unknown, the portion of the wheel left exposed will indicate the correct derivation of Ohm's Law.

Solving for E_{TOTAL}, I_{TOTAL} and R_{TOTAL}

When solving for any total value, the units for each variable are very important to note. E should be in volts, I in amperes, and R in ohms.

E_{TOTAL}

Solving for E_{TOTAL} the correct formula to be used is $E = I \times R$. If a simple circuit had .5 amps (I) and 125 ohms (R) known, then

$E = I \times R$
$E = .5A \times 125$
$E = 62.5$ v

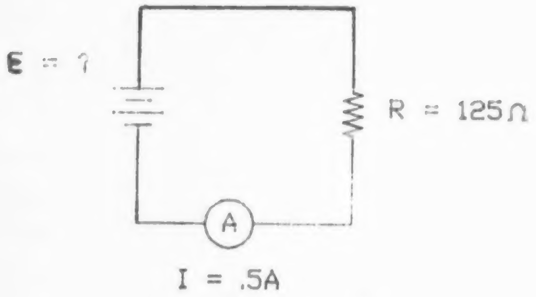


Figure A 5.1-2

I_{TOTAL}

Solving for I_{TOTAL} the correct formula to be used is $I = E/R$. If a simple circuit had E = 200v and 50 ohms = R, then

$$I = \frac{E}{R} \text{ or } I = \frac{200v}{50} \text{ or } I = 4A$$

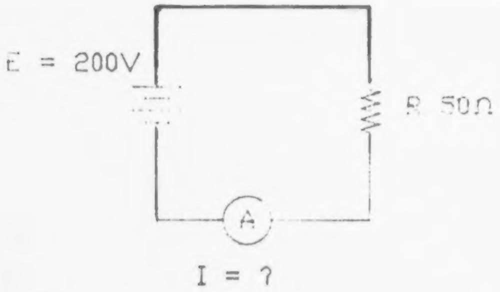


Figure A 5.1-3

R_{TOTAL}

Finally, solving for R_{TOTAL} the correct formula to be used is R = E/I . If a simple circuit had E = 15v and I = .005A then

$$R = \frac{E}{I} \quad \text{or} \quad R = \frac{15}{.005} \quad \text{or} \quad R = 3000 \text{ ohms}$$

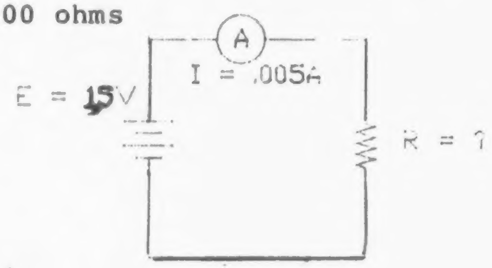


Figure A 5.1-4

Remember, in all three previous circuit examples, the circuit variables had all been reduced to their simplest value.

Finding Individual Values Using Ohm's Law

Voltage

To find an individual voltage drop in a circuit, you must use only the individual values of E, I and R that relate to that component. As an example, See Figure A 5.1-5.

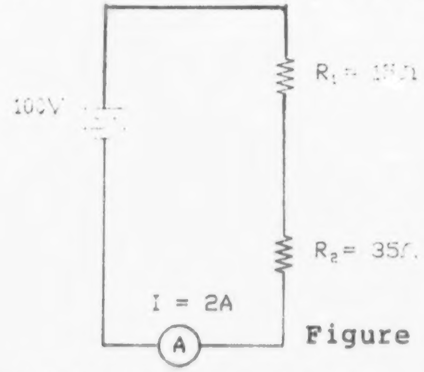


Figure A 5.1-5

What would be the voltage drop across R_1 (E_{R1}) in this circuit? The correct formula to use would be $E_{R1} = I_{R1} \times R_1$ (I_{R1} will be equal to I_{TOTAL} because this is a series circuit). Therefore $E_{R1} = 2A \times 15$ or $E_{R1} = 30v$. Also $E_{R2} = I_{R2} \times R_2$ or $E_{R2} = 2A \times 35$ which equals $E_{R2} = 70v$. Now using Kirchhoff's Voltage Law ($E_T = E_{R1} + E_{R2} + E_{R3} \ldots E_{RN}$ we know 30v + 70v = 100v

Finding Current in a Parallel Branch

In order to find individual branch currents in a parallel circuit, the branch voltages and resistances must be known. Therefore, given this circuit, See Figure A 5.1-6.

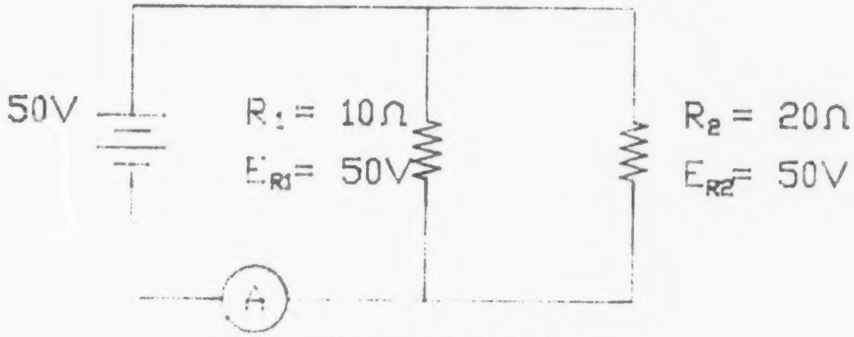


Figure A 5.1-6

$I_{R1} = E_{R1}$ or $I_{R1} = \frac{50v}{10}$ or $I_{R1} = 5A$.

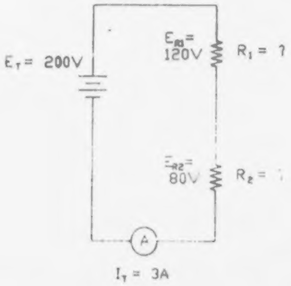
Likewise, if $I_{R2} = \frac{E_{R2}}{R_2}$, then $I_{R2} = \frac{50\ v}{20}$ or

$I_{R2} = 2.5A$.

Together the branch currents equal 7.5A. This can be proven using Kirchhoff's Current Law ($I_{TOTAL} = I_{R1} + I_{R2} + I_{R3} \cdots I_{Rn}$).

Finding Individual Resistances

When looking for unknown resistor values in a circuit, the voltage and current variables must be known. Given this circuit,



find $R_1 = \frac{E_{R1}}{I_{R1}}$ (again $I_{R1} = I_{TOTAL}$). So, $R_1 = \frac{120\ v}{3A}$ which equals $R_1 = 40\,\Omega$. To find R_2 the same procedure can be followed. $R_2 = \frac{E_{R2}}{I_{R2}} = \frac{80\ v}{3A} = 26.7\Omega$.

To learn more on applying Ohm's Law to circuits, return to the Learning Steps portion of this guide. Continue on.

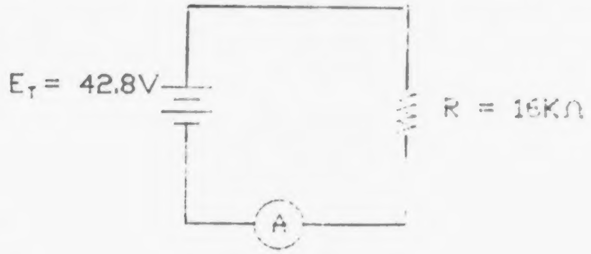
ACTIVITY SHEET

A 5.2

OHM'S LAW

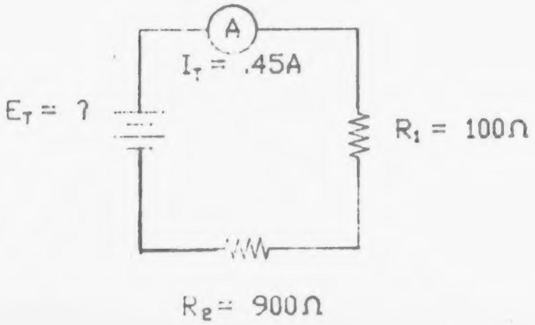
DIRECTIONS: Complete each question. Do not continue with any portion of this guide until the Activity Sheet has been completed. If you need any help, see your instructor.

1.


E_T = 42.8V
R = 16KΩ
A

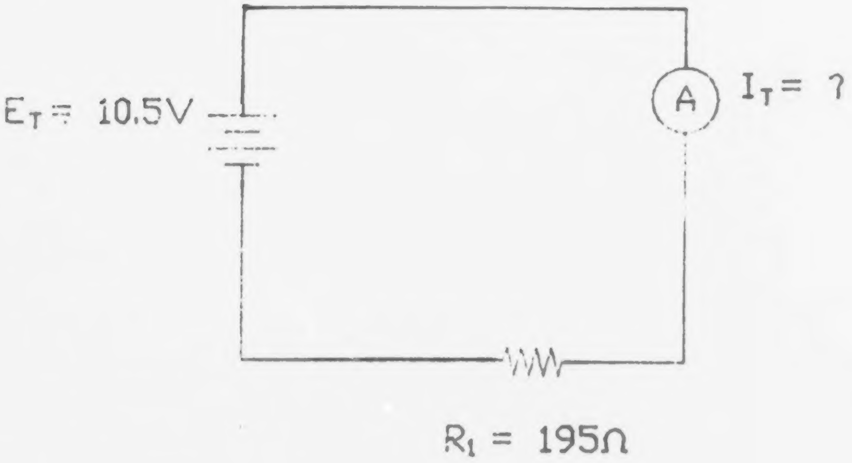
I_t = ________

2.


A
I_T = .45A
E_T = ?
R_1 = 100Ω
R_2 = 900Ω

E_t = ________

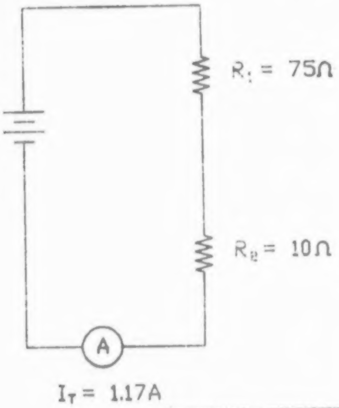
3.


E_T = 10.5V
A
I_T = ?
R_1 = 195Ω

I_t = ________

ACTIVITY SHEET A 5.2 CONT'D.

4.

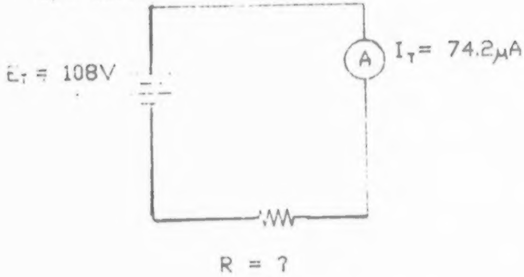


R_1 = 75Ω
R_2 = 10Ω
A
I_T = 1.17A

E_{R1} = ________

E_{R2} = ________

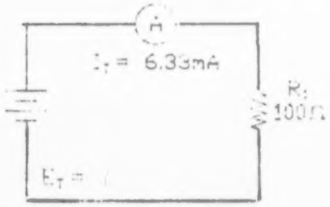
5.



E_T = 108V
A
I_T = 74.2μA
R = ?

R_t = ________

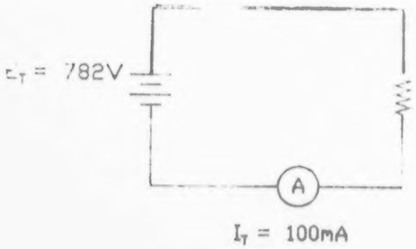
6.



A
I_T = 6.33mA
R_1 100Ω
E_T = ?

E_t = ________

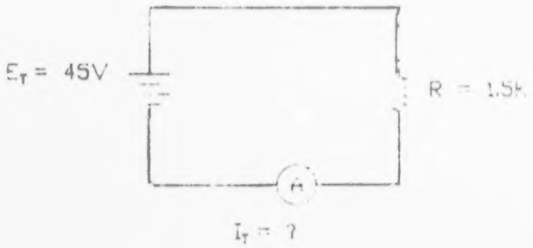
7.



E_T = 782V
A
I_T = 100mA

R_1 = ________

8.

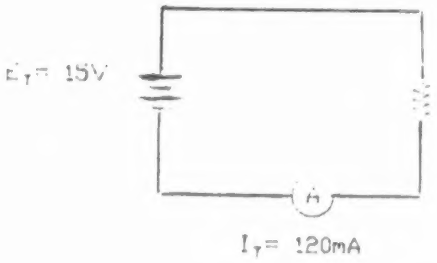


E_T = 45V
R = 1.5k
A
I_T = ?

I_t = ________

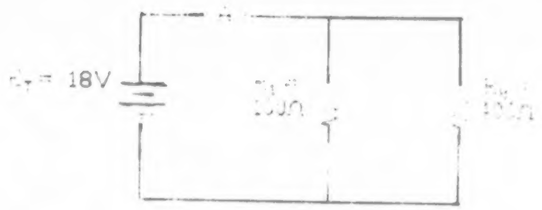
ACTIVITY SHEET A 5.2 CONT'D.

9.


$E_T = 15V$
A
$I_T = 120mA$

R_t = ________

10.


A
$E_T = 18V$
$R_1 =$
100Ω
$R_2 =$
100Ω

I_{R2} = ________

ACTIVITY SHEET A 5.2

ANSWER KEY

1. 2.6 mA
2. 450v
3. 53.8 mA
4. E_{R1} = 87.75v E_{R2} = 11.7v
5. R_t = 1.46 MΩ
6. E_t = 633 mV
7. R_1 = 7.82 KΩ
8. I_t = 30 mA
9. R_t = 125Ω
10. I_{R1} = 180 mA I_{R2} = 45mA

ACTIVITY SHEET

A 5.3

OHM'S LAW PROBLEMS

1. A neon electric sign draws 1.25 amps. If its resistance is 92 ohms, what voltage does it require?

2. What current is drawn from a 6.2KΩ electric clock when operated from a 117 volt line?

3. What is the resistance of a motor if it draws 5.2A from a 120-V line?

4. The resistance of a telephone receiver is 420Ω. If the current is 57mA, what voltage is needed?

5. Find the current used by a bell of 8.5 ohm resistance when used on 12.6-V circuit.

6. If the voltage drop across a resistor is measured to be 65mV and the current through it is 43μA, what is the value of resistance?

7. If an ohmmeter is constructed from a 9V battery and a 0-50 microamp meter movement, what is the range of resistance R it can measure? Assume the meter can be read with an accuracy of 0.5 Assume it has no internal resistance.

8. A source of applied voltage produces mA through 10-M ohm resistance. How much is the applied voltage?

9. Calculate the IR voltage for the following:

   a. 68 micros A through 22 MEGA ohm
   b. 2.3mA through 47 Kilo ohms
   c. 625 NANO amps through 1 milli ohm

10. In a transistor circuit, a 1 K ohm resistor has 20 micro amps through it. The voltage across this resistor is what?

ACTIVITY SHEET A 5.3

ANSWER SHEET

1. V = I x R V = 1.25A x 92 ohms = 115 volts

2. I = V/R = 117/6.2K ohm = 19 mA

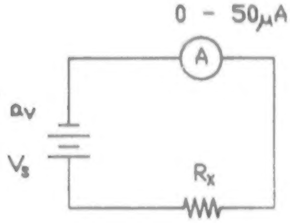
3. R = V/I = 120/5.2A = 23 ohms

4. V = I x R = 57mA x 420 ohm = 23.94 24 volts

5. I = V/R = 12.6/8.5 = 1.5 volts

6. R = V/I = 64 x 10^{-3}/43 x 10^{-6} 1.5K ohms

7.



R x = Vs/A Full Scale R x = 9/50 A = 180K ohm
Full scale

R x = Vs/0 = Range 180K to ∞

= Vs/0.5 A = 9/0.5 A = 180M ohms 180K - 180 M

8. V̇ = I x R = 1mA x 10M ohm = 10 Kilo volts

9. a. V = I x R V = 68 A x 22M = 1.5 Kilo Volt
   b. V = I x R V = 2.3mA x 47K = 110 volts
   c. V = I x R V = 625 NANO A x 1 mili ohm =
   630 x 10^{-12} Volts

10. V = I x R V = 20 μA x IKΩ + 20 mA

PROGRAM: ELECTRONICS

TASK: OHM'S LAW

TASK #: A 5.4

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

GIVEN ACCESS TO ALL NECESSARY TOOLS AND EQUIPMENT, APPLY OHM'S LAW IN A DC CIRCUIT.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

OHM'S LAW

A 5.4

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the circuit wired according to the schematic?	Y N
* 2.	Does the circuit function properly?	Y N
* 3.	Was necessary data recorded?	Y N
4.	Was the correct equipment used?	Y N
* 5.	Was the equipment used correctly?	Y N
* 6.	Were safety precautions followed?	Y N
7.	Was the equipment returned to proper storage area?	Y N

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

STUDENT'S SCORE ____

OHM'S LAW

EXAM

A 5.5

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Ohm's Law. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer a minimum of _8_ out of _10_ items correctly, 80%.

OHM'S LAW

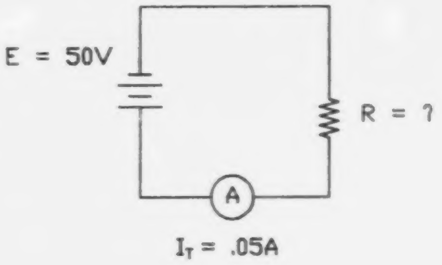
EXAM

A 5.5

1. Ohm's Law states that current is directly proportional to voltage and directly proportional to resistance.

   A. True
   B. False

2. Given the circuit, Figure A 5.5-1,



R_t = ________?

Figure A 5.5-1

   A. 10000 KΩ
   B. 1000 K Ω
   C. 1000 Ω
   D. 100 K Ω

3. If current is known in a circuit, resistance is also known.

   A. True
   B. False

4. Given the circuit, Figure A 5.5-2, solve for E_t.

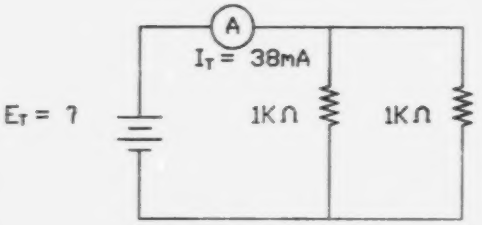


Figure A 5.5-2

   A. 19v
   B. 76v
   C. 38v
   D. 3.8v

5. If a circuit has a power source of 10v and 55 mA of current, how much resistance is present?

   A. 272 Ω
   B. 43.1 Ω
   C. 1.3 KΩ
   D. 181 Ω

6. If the voltage applied to a circuit is doubled but the resistance remains the same, the current value will ______.

   A. decrease by 1/2
   B. double
   C. triple
   D. decrease non-linearly

7. What voltage is required to produce 2A of current through 60Ω ?

   A. 30v
   B. 60v
   C. 120v
   D. 240v

8. A relay coil having 275Ω is across 4.5v. What current value will it draw?

   A. 16.3 mA
   B. 420 A
   C. 100 mA
   D. 7.3A

9. A 7KΩ resistor in a receiver has 5 mA of current flowing through it. What voltage drop is developed across it?

   A. 41v
   B. 30v
   C. 25v
   D. 35v

10. To find an unknown current value in a circuit when resistance and voltage are known, use _________.

   A. $E = I \times R$
   B. $I = R/E$
   C. $I = \frac{E}{I}$
   D. $I = \frac{E}{R}$

EXAM A 5.5

ANSWER KEY

1. B
2. C
3. B
4. A
5. D
6. B
7. C
8. A
9. D
10. D

ELECTRONICS

ANALZYING DC CIRCUITS

A 6: IDENTIFY AND COMPUTE ELECTRIC POWER

TASK:	Identify and compute electric power.
PURPOSE:	When you use electricity, you usually want it to do some kind of work. "Power" can be described as the rate at which work is done. Since many circuits have various loads requiring specific power values, it is important that you understand how to identify and compute electric power. You will investigate power in this learning guide.
OBJECTIVE:	Given access to all necessary tools and equipment, you will identify and compute electric power. To master this task, you must score 80% on a written exam and performance checklist.

ESTIMATED CLASS TIME: 4 HOURS

IDENTIFY AND COMPUTE ELECTRIC POWER

LEARNING STEPS

A 6

READ: Information Sheet A 6.1, "Power."

READ: Information on power in one or more resources listed below. See your instructor.

VIEW: Audio/visual material on power. Contact your instructor.

COMPLETE: Activity Sheet A 6.2 on "Power."

COMPLETE: Activity Sheet A 6.3 on "Power."

COMPLETE: Activity sheet A 6.4 on "Power Problems."

COMPLETE: Lab Performance on power. Contact your instructor for this lab.

COMPLETE: Performance Checklist A 6.5. Contact your instructor.

REVIEW: All material covered in this learning guide and information presented by your instructor.

COMPLETE: Written Exam A 6.6. Contact your instructor.

IDENTIFY AND COMPUTE ELECTRIC POWER

RESOURCES

A 6

1. BASIC ELECTRICITY AND CIRCUIT CONCEPTS: VOL. 1, DC CIRCUITS, Oliva and Dale (Radio Shack: Texas Instrument Learning Center, 1979), 4th Edition. Chapter 1.

2. DC ELECTRONICS (Heathkit Educational Systems, 1984). Units I & II.

3. BASIC ELECTRONICS, Grob (McGraw-Hill, 1984). Chapter 1.

4. INTRODUCTION TO ELECTRICITY AND ELECTRONICS, Bell & Howell Schools (DeVry Institute of Technology, 1984). Chapter 1001.

5. INTRODUCTION TO INDUSTRIAL ELECTRICITY-ELECTRONICS (Oklahoma Trade and Industrial Education).

6. ELECTRONICS: PRINCIPLES AND APPLICATIONS, Badrkhan and Larky (South Western Pub.). Chapter 1.

7. ELECTRICITY ONE-SEVEN, Mileaf (Hayden). Chapter 1.

8. ELECTRONIC COMMUNICATION, Schrader (McGraw-Hill Pub. Co.). 5th Ed. Chapter 1.

INFORMATION SHEET

A 6.1

POWER

In addition to the three basic electrical quantities (current, voltage, and resistance) a fourth quantity is also very important. This quantity is known as power. Power is defined as the rate at which work is done. In other words, power refers to the amount of work done in a specific length of time. The use or loss of power in a circuit is called dissipation, and is usually in the form of a heat loss.

The unit of power is a watt. Also, one watt is the amount of power used in a circuit when one ampere of current flows as the result of one volt of applied emf.

Power is directly proportional to both voltage and current. Given this fact, Watt's Law can be stated as: $P = I \times E$.

Like Ohm's Law, Watt's Law has three variations.

1. $P = I \times E$
2. $I = \frac{P}{E}$
3. $E = \frac{P}{I}$

Watt's Law and Ohm's Law can be combined to find power whenever resistance is known and either voltage or current is only known. The resulting derivations are

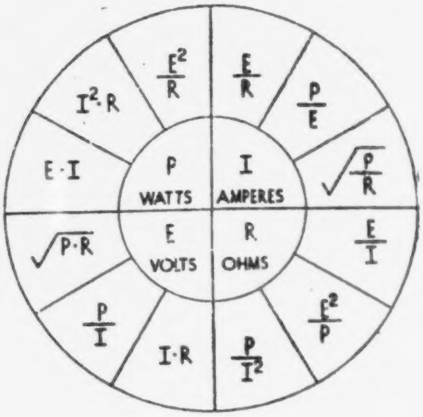
$$P = I^2R \text{ and } P = \frac{E^2}{R}.$$

Computing electric power in a circuit is very important because many components and devices have specific power requirements that must be followed. Resistors, for example, have not only an ohm value but also have a wattage rating which tells how much heat they can dissipate.

In most electronic devices, the heat produced by resistors represents wasted power. Since electrical power costs money, attempts are made to keep the power lost in components at a minimum.

The wheel diagram shows the relationship Watt's Law has with Ohm's Law. Notice how many different variations of formulas are available to find power in a circuit. See Figure A 6.1-1.

OHM'S LAW & WATT'S LAW RELATIONSHIPS


$I^2 \cdot R$
$\frac{E^2}{R}$
$\frac{E}{R}$
$\frac{P}{E}$
$E \cdot I$
P
WATTS
I
AMPERES
$\sqrt{\frac{P}{R}}$
$\sqrt{P \cdot R}$
E
VOLTS
R
OHMS
$\frac{E}{I}$
$\frac{P}{I}$
$I \cdot R$
$\frac{P}{I^2}$
$\frac{E^2}{P}$

E = Voltage

R = Resistance

I = Current

P = Power

Figure A 6.1-1

"Power" and "energy" are sometimes used synonymously. But, really these two terms do not mean the same thing. Power is the ability to do work and is measured in watts. Energy is usually computed by multiplying the amount of power by the length of time the power is used. One watt of power working for one second is known as a watt-second, or as a "joule" of energy.

True power and apparent power are always two items of importance to consider when measuring power in a circuit. Apparent power is the power assumed to be present in a circuit. True power, though, is the actual power present in the circuit. Given is a list of terms and definitions to help you understand power. Also, there are some problems for calculating power in a circuit. Analyze each problem. Once finished, return to the Learning Steps portion of your guide.

I. Terms and definitions

- A. Electrical power--Rate of doing work; expressed in units of watts or joules per second
- B. Milliwatt--One one-thousandth of a watt
- C. Kilowatt--One thousand watts
- D. Megawatt--One million watts
- E. Electrical energy--Amount of work; product of power and time, usually expressed in kilowatt-hours
- F. Dissipate heat--Give off heat by radiation, conduction, and convection
- G. Load--Equipment or devices being supplied power
- H. Line loss--Power wasted in electrical wires due to heating caused by electrical current flow; heat loss of lines
- I. Kilovolt--One thousand volts
- J. Voltage drop--Voltage reduction, usually due to resistance
- K. Internal resistance--Resistance that is part of the internal electrical, chemical, and mechanical workings of an electrical device; considered a single resistor
- L. Impedance--Total opposition of a device or circuit to current flow; accounts for all alternating current and direct current effects
- M. Maximum power transfer point--Point where internal resistance of the load is equal to the resistance of the source or supplier of power; point of matched impedance
- N. Real power--Component of apparent power that represents true work; expressed in watts, it is equal to volt-amperes multiplied by the power factor

INFORMATION SHEET A 6.1 CONT'D.

II. Abbreviations associated with electrical power

A. mW--Milliwatt

B. kW--Kilowatt

C. MW-Megawatt

D. kW-hr--Kilowatt-hour

E. kV-Kilovolt

F. E--Voltage; energy

G. DC--Direct current

H. AC--Alternating current

I. W--Watt

J. V--Volt

K. A--Ampere

L. VDC--Volts direct current

M. VAC--Volts alternating current

N. J--Joule

O. Ω --Ohm

III. Electrical power formulas

A. Voltage and amperage--$P = I E$

B. Resistance and amperage--$P = I^2R$

(NOTE: I^2R is an equivalent expression for I x I x R.)

IV. Calculating electrical power

A. Amperage and voltage measurements--Use the formula, $P = IE$

EXAMPLE: An electric lamp made to operate at 12 volts DC has a current draw of 5 amperes. What is the lamp's power rating?

Solution: $P = IE$

$= 5\ A \times 12\ V$

$= 60\ W$ (Lamp's power rating)

B. Ampere and resistance measurements--Use the formula $P = I^2R$

EXAMPLE: A 1200 foot (366 meter) line of electrical wire connects an alarm buzzer to a temperature sensor 600 feet away. If the buzzer operates at 2 amperes and the wire has a resistance of 6.39 ohms per 1000 feet, what will be the rate of energy loss in the conductor?

Solution: The 1200 foot wire has 1.2 x 6.39 ohms for a total resistance of 7.67 ohms

$P = I^2R$

$= 2 \times 2 \times 7.67$

$= 30.68\ W$ (Energy loss in the conductor)

V. Calculating electrical energy used in direct current circuits--Multiply power times the time applied ($E = P \times \text{Time}$), usually expressed as kilowatt-hours (kW-hr)

EXAMPLE: Eight electric lamps are operated each night to light a billboard. The lamps are each 150 watts, and they operate an average of 11 1/2 hours per night. What is the energy used, on the average, each night?

(NOTE: First find the total power then multiply times the hours.)

Solution: Total power = 8 Lamps x 150 W

= 1,200 W

$E = P \times \text{Time}$

$= 1{,}200\ W \times 11.5$ hrs

= 13,800 W-hrs

= 13.8 kW-hrs

EXAMPLE: An emergency generator is powered by a diesel engine. The diesel engine uses three 24-volt batteries in parallel for starting power. If each of the three batteries delivers 250 amperes for 15 minutes before the engine starts, how much electrical energy is required?

Solution:

$$
\begin{aligned}
P &= IE \\
&= 3 \text{ Batteries} \times 250 \text{ A} \times 24 \text{ V} \\
&= 18{,}000 \text{ W} \\
E &= P \times \text{Time} \\
&= 18{,}000 \text{ W} \times 15 \text{ min} \\
&= 18{,}000 \text{ W} \times .25 \text{ hr} \\
&= 4500 \text{ W-hrs} \\
&= 4.5 \text{ kW-hrs}
\end{aligned}
$$

VI. Power ratings

A. Power requirement--Power at which a device is intended to operate; probably will not operate properly at a lower power; may become damaged at a higher power operation

EXAMPLES: 100 watt light bulb, 40 watt soldering iron, 35 kilowatt electric heating unit

B. Heat dissipation--Maximum power a device can dissipate without possible damage; usually much higher than the intended operating power; damage is certain at higher power operations

EXAMPLES: 2 watt resistor, 1/4 watt transistor, 500 milliwatt (1/2 watt) diode

C. Power output--Maximum power which a device can deliver to a load; power output in form of heat, sound, and mechanical energy; may operate at or anywhere below the output rating

EXAMPLES: 30 kilowatt direct current generator, 70 ampere-hour automobile battery with nominal 12 volts understood

(NOTE: Usually power output specifications are applied to AC equipment such as a 5 watt radio transceiver, 50 watt stereo speaker, 40 watt amplifier, 50 kilovolt-amperes transformer, etc.)

VII. Calculating the effects of conductor resistance

A. Heat loss--Use the formulas, $P = I^2R$ and $E = P \times \text{Time}$

EXAMPLE: A three-wire transmission line between two cities carries 100 amperes at 13.8 kV in each line. The resistance of each wire is calculated to be 8.5 ohms for the total distance. What is the total heat loss in kilowatt-hours each hour?

Solution: $P = I^2R$

$= 100 \times 100 \times 8.5$

$= 85$ kW

$E = P \times \text{Time}$

$= 85 \text{ kW} \times 1 \text{ hr}$

$= 85$ kW-hrs per line

E (total) = 3 Lines x 85 kW-hrs

E (total) = 255 kW-hrs per hour

(NOTE: The example above is actually suggestive of AC power which behaves differently than DC power in some respects. Heat loss is calculated virtually the same, however. AC power is considered in another unit of instruction.)

B. Voltage drop--Use the formula, $E = IR$ (Ohm's Law)

EXAMPLE: To start a gasoline powered fork-lift, a worker uses "jumper-cables" from a truck battery. The starter draws 150 amperes of current, and each cable has .025 ohms of resistance, including the end connectors. What is the voltage drop of the cables?

Solution: $E = IR$

$= 150$ A x .025 Ohms per wire x 2 wires

$= 7.5$ V (Voltage drop of cables)

(NOTE: The voltage was "dropped" twice in the circuit, once in each wire. Notice that if the battery was 12 volts only, 4.5 volts would be left for the starter motor.)

VIII. Reasons for using high voltage to supply electrical power to distant loads

A. Smaller conductor size will supply same power.

EXAMPLE: To supply 44 kilowatts to a remote electric pump motor requires wiring of size AWG #2 at 220 volts and 200 amperes but only size AWG #12 at 1000 volts and 44 amperes.

B. There is less power loss in lines.

EXAMPLE: Because heat loss is expressed as $P = I^2R$, the transmission of 13.8 megawatts of power at 100 amperes and 138 kilovolts is 6.25 times more costly due to line loss than the same 13.8 megawatts at 345 kilovolts and 40 amperes.

C. There is less voltage drop in lines.

EXAMPLE: Because voltage drop is equal to $E = IR$, the voltage drop of a 120-volt line at 100 amperes and .1 ohm is 10 volts. The same line would supply the same power at 240 volts and 50 amperes and have a voltage drop of 5 volts.

IX. Maximum power transfer--Maximum power transfer is accomplished when load resistance equals the internal resistance of the source of power; also called impedance matching

EXAMPLE: A 24-volt battery has an internal resistance of 4 ohms. If a lamp is attached with a resistance of 2 ohms, then the total circuit has 6 ohms, and I = 4 amperes, P (of the lamp) = 32 watts. If the lamp is 4 ohms, then R (total) = 8 ohms, I = 3 amperes, P (of the lamp) = 36 watts. If the lamp is 6 ohms, then R (total) = 10 ohms, I = 2.4 amperes, P (of the lamp) = 34.56 watts.

ACTIVITY SHEET

A 6.2

POWER

DIRECTIONS: Complete each question. DO NOT CONTINUE with any portion of this guide until the Activity Sheet has been completed. If you need any help, see your instructor.

1. Define power:

2. Find the power dissipated by R_3. See Figure A 6.2-1.

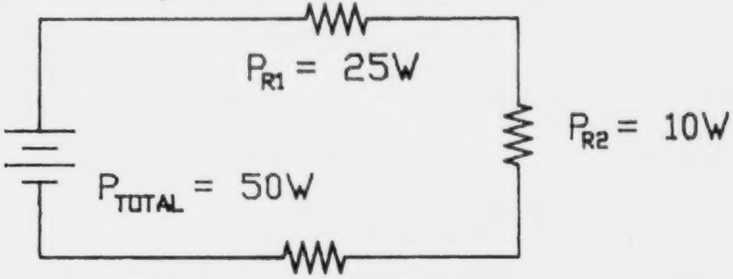


Figure A 6.2-1 P_{R3} = ?

3. What is the power usage of a resistor passing 20A of current that has a resistance of 65 Ω ?

4. A 120V electric iron has 43 Ω resistance. How much heating power does it produce?

5. Across how many volts must a 600W heater be connected if it is drawing 5A?

6. A receiver across a 120V line has .75A flowing through it. How much power is being used?

7. A 1.7K Ω resistor must carry 8mA. What should the power rating of the resistor be?

8. A 25W - 500 Ω resistor can be safely connected across how much voltage?

9. How much current will flow in a television set that is rated at 240W when connected across 120V?

10. What is the resistance of a 3W - 120V lamp?

ACTIVITY SHEET A 6.2

ANSWER SHEET

1. The rate at which work is done.
2. 15W
3. 26KW
4. 335W
5. 120V
6. 90W
7. .109 W or 1/4 W to be safe. A 1/8 Watt could theoretically work also.
8. 112V
9. 2A
10. 4.8KΩ

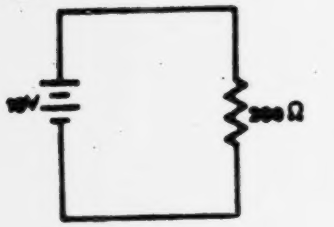
ACTIVITY SHEET

A 6.3

POWER

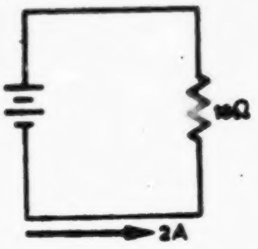
COMPLETE:

①



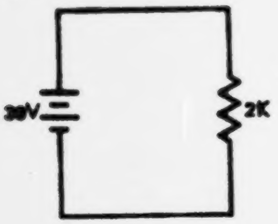
P= ________

②



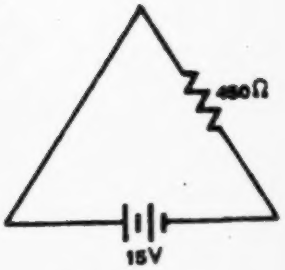
P= ________

③



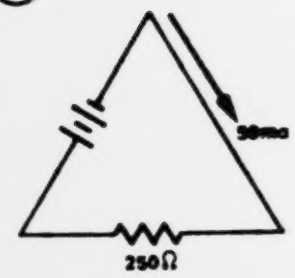
P= ________

④



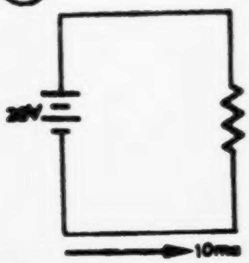
P= ________

⑤



P= ________

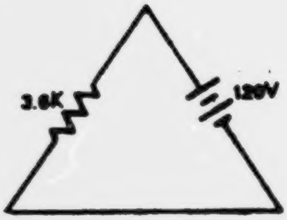
⑥



P= ________

ACTIVITY SHEET A 6.3 CONT'D.

⑦



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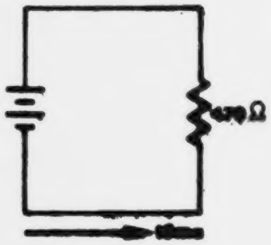

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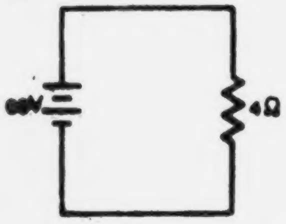


10. What power is dissipated in a 200V heating element having a resistance of 9.52 Ω ?

ACTIVITY SHEET A 6.3

ANSWER SHEET

1. 0.5W
2. 40W
3. 0.45W
4. 0.5W
5. 0.625W
6. 0.2W
7. 0.4W
8. 0.047W
9. 900W
10. 4200W

ACTIVITY SHEET

A 6.4

POWER PROBLEMS

1. The voltage across a resistive heater producing 100W is increased by a factor of three. How much power, P, will the heater now dissipate?

2. If a thermistor draws 237μA at 9.0 volts, what is its resistance R? How much electrical power, P, is it using?

3. A 1/2 watt resistor has the color code (green, blue, yellow, silver). What is the maximum current, Imax, it can carry?

4. If the power output of a 12 ohm dc heater is 500 watts, what is the voltage, V, across the heater?

5. A power supply can deliver 100mA of 15 volts. What is the power rating, P max?

6. A circuit contains a 1/2 watt resistor of 0.38M ohms. What is the maximum allowable current, Imax, that the resistor can carry?

7. A certain 9 volt transistor radio battery will supply a current of 50 mA for 50 hours. How long will the battery operate if the radio consumes electric energy at the rate of 450 mW?

8. What is the cost of operating a 150-W soldering iron for 8 hours if electricity costs 0.035 cents per KWH?

9. What current is required for a 1/2 hp motor connected to a 120V line?

10. How much power is dissipated by an LED with 20mA of current flowing through it and 1.4 volts dropped across it?

ACTIVITY SHEET A 6.4

ANSWER KEY

1. $P = \frac{E^2}{R}$ $P = \frac{3(E^2)}{R}$ P increase by 3

   or $P = E \times I$ $P = 3E \times I$ P increase by 3

2. $R = V/I$ $R = \frac{9.0}{237\mu A}$ = 37.9K ohms

   $P = V \times I$ P = 9.0V x 237 A = 2.13 mW

3. P - .5WAH max.   R = 560,000 +/- 10%

   $I = \sqrt{P/R}$ $I = \sqrt{.5/504\text{Kohm}}$ R min. = 504Kohms

   I = 996 A max

4. R = Rohms P = 500 watts $V = \sqrt{PR} = \sqrt{500 \times 12}$ = 77.5 Volts

5. I = 100 mA V = 15 volts P = I x V = 100mA x 15 V = 1.5 watts

6. P = 0.5 watts $R = 0.38 \times 10^{+6}$ ohms $I = \sqrt{P/R}$ = 1.15 mA

7. Battery: W = Pt = V x I x T = 9 x 0.05 x 50 x 3600 = 81,000J
   Radio: W = 450 mW = 0.45J/sec   t = 81,000/0.45 = 50 hrs.

8. 150 W = .15 KW x 8 = 1.2 KW H x 0.035 4 cents

9. 1 hp 746 watts 1/2 HP = 373 watts V = 120 volts

   $I = P/V$ $I = \frac{373W}{120V}$ = 3.11 amps

10. I = 20mA V = 1.4 volts   P = V x I   P = 1.4 x 20mA = 28 mW

PROGRAM: ELECTRONICS

TASK: IDENTIFY AND COMPUTE ELECTRIC POWER

TASK #: A 6.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

GIVEN ACCESS TO ALL NECESSARY TOOLS AND EQUIPMENT, IDENTIFY AND COMPUTE ELECTRIC POWER.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out 7 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

IDENTIFY AND COMPUTE ELECTRIC POWER

A 6.5

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the circuit wired according to the schematic?	Y N
* 2.	Does the circuit function properly?	Y N
* 3.	Was necessary data recorded?	Y N
4.	Was the correct equipment used?	Y N
* 5.	Was the equipment used correctly?	Y N
* 6.	Were safety precautions followed?	Y N
7.	Was the equipment returned to proper storage area?	Y N

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

STUDENT'S SCORE ____

POWER

EXAM

A 6.6

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on identifying and computing electric Power. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer a minimum of 8 out of 10 items correctly, 80%.

POWER

EXAM

A 6.6

1. A watt is the amount of power used in a circuit when one ampere of current flows as the result of one volt of applied emf.

   A. True
   B. False

2. What resistance does the filament of a light bulb have if 100W of power is dissipated when placed across 120V.

   A. 4.0 KΩ
   B. 21 Ω
   C. 96.5 MΩ
   D. 144 Ω

3. 1,000 watts equals 1 MegaWatt.

   A. True
   B. False

4. .001W is the same as __________.

   A. 100 mW
   B. 1000 MegaWatts
   C. .01 mW
   D. 1 mW

5. Calculate electrical power from measurements of amperage, voltage, and resistance.

   An electric hot water heater has a measured current use of 14 amperes while it is operating at 220 volts. What is its power consumption rate?

6. Calculate electrical energy used in direct current circuits in the problem below.

   An electric fork lift operates from four 24-volt batteries connected in parallel. If each battery delivers 25 amperes continuously during operation, how much power is used during one-half hour of operation?

7. Calculate effects of conductor resistance.

(NOTE: Use the formula $P = I^2R$ and $E = P \times Time$.)

A heater is made from resistance wire having a total resistance of nine ohms. The heater operates at 20 amperes. What quantity of heat does the heater supply in two hours time?

8. With 10V across 5Ω R, the current I is _________A.

A. 2
B. 4
C. 6
D. 10

9. A television receiver using 240W from a 120V power line draws current I = __________A.

A. .5
B. 2
C. 6
D. 20

10. The power of 50W = 2A x __________V?

A. 40
B. 25
C. 75
D. 10

EXAM A 6.6

ANSWER KEY

1. A
2. D
3. B
4. D
5. 3080 Watts
6. 1.2 Kilowatt hours, or 1.2 kW-hrs
7. 7.2 Kilowatt hours, or 7.2 kW-hrs
8. A
9. B
10. B

ELECTRONICS

ANALYZING DC CIRCUITS

A 7: SERIES CIRCUITS

TASK: Analyze, construct, and troubleshoot basic series resistive circuits using Ohm's Law and Kirchhoff's Law.

PURPOSE: One of the most fundamental types of circuits is the series circuit. To be able to analyze and troubleshoot electronic circuits, schematics, or diagrams, you must have a thorough understanding of series circuit characteristics. This learning guide will provide you with important concepts that are necessary for understanding series circuits.

OBJECTIVE: Given access to all necessary tools and equipment, you will analyze, construct, and troubleshoot basic series resistive circuits using Ohm's Law and Kirchhoff's Law. To master this test, you must score 80% on a written exam and performance checklist.

ESTIMATED CLASS TIME: 6 HOURS

SERIES CIRCUITS

LEARNING STEPS

A 7

READ:	Information Sheet A 7.1 "Series Circuits."
READ:	Information on series circuits from the following resource list.
VIEW:	Audio/Visual material on series circuits, contact your instructor.
COMPLETE:	Activity Sheet A 7.2 on series circuits.
COMPLETE:	Activity Sheet A 7.3 on series circuit problems.
COMPLETE:	Lab Performance on series circuits. Contact your instructor for this lab.
COMPLETE:	Performance Checklist A 7.4. Contact your instructor.
REVIEW:	All material covered in this learning guide and information presented by your instructor.
COMPLETE:	Written Exam A 7.5.

SERIES CIRCUITS

RESOURCES

A 7

1. BASIC ELECTRICITY AND CIRCUIT CONCEPTS: VOL. 1, DC CIRCUITS, Oliva and Dale (Radio Shack: Texas Instrument Learning Center, 1979), 4th Edition. Chapter 1.

2. DC ELECTRONICS (Heathkit Educational Systems, 1984). Units I & II.

3. BASIC ELECTRONICS, Grob (McGraw-Hill, 1984). Chapter 1.

4. INTRODUCTION TO ELECTRICITY AND ELECTRONICS, Bell & Howell Schools (DeVry Institute of Technology, 1984). Chapter 1001.

5. INTRODUCTION TO INDUSTRIAL ELECTRICITY-ELECTRONICS (Oklahoma Trade and Industrial Education).

6. ELECTRONICS: PRINCIPLES AND APPLICATIONS, Badrkhan and Larky (South Western Pub.). Chapter 1.

7. ELECTRICITY ONE-SEVEN, Mileaf (Hayden). Chapter 1.

8. ELECTRONIC COMMUNICATION, Schrader (McGraw-Hill Pub. Co.). 5th Ed. Chapter 1.

INFORMATION SHEET

A 7.1

SERIES CIRCUITS

Electronic circuits are generally one of three basic circuit configurations: series, parallel, or series/parallel. In this learning guide we'll take a close look at series circuits.

If electronic components are going to work together to perform a desired task, then they must be connected in a circuit that will enable them to carry out that task. So, in order to proceed let's define the term "circuit." A circuit must have a minimum of three components: 1) a power source 2) a load 3) connecting wires or equivalent. A fourth component that can be added to the list is a switch to control the circuit.

A circuit in which components are connected end to end such that current has only one path to flow is called a SERIES circuit. Look at Figure A 7.1-1 which shows a series circuit.

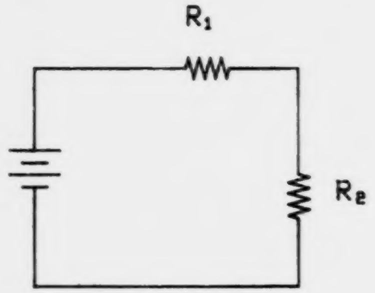


Figure A 7.1-1

[NOTE: In this learning guide only series resistive circuits are discussed. But, other components can be combined in series for various circuit results.]

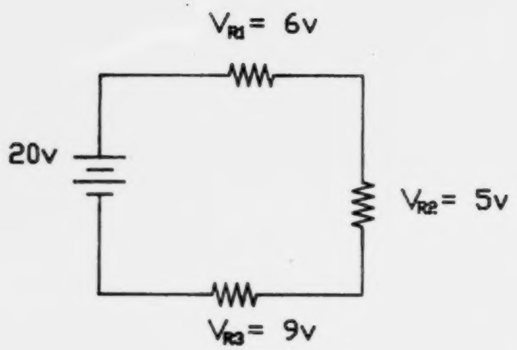
Remember from your previous learning guide #2 there are three distinct characteristics of any circuit that can be analyzed: 1) voltage 2) current 3) resistance. If you need to review them, do so now before proceeding.

In a series circuit, the sum of the individual voltage drops in a circuit equals the total applied voltage. Stated another way:

V total = VR1 + VR2 + VR3......VRn

(Kirchhoff's Voltage Law)

Analyze Figure 7.1-1 to check Kirchhoff's Voltage Law.



$$V_{R1} + V_{R2} + V_{R3} = V_t$$
$$6_v + 5_v + 9_v = 20_v$$

Figure A 7.1-2

Another general rule to follow with a series circuit is the sum of each individual resistance in a series circuit will equal the total resistance of the circuit. Again, there's another way to express this idea mathematically. That is:

R total = R1 + R2 + R3.......Rn

Since current in a series circuit has the same value at any point within the circuit, we can say:

I total = IR1 = IR2 = IR3....... = IRn

The current through any resistance in a series circuit is the total current value. Figure A 7.1-3 illustrates this concept.

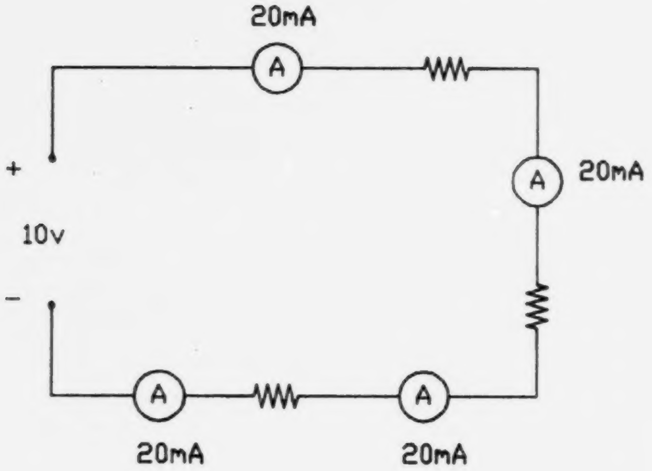


FIGURE A 7.1-3

You've just been introduced to three basic characteristics of series circuits.

1) V total = VR1 + VR2 + VR3.....+VRn
2) R total = R1 + R2 + R3 ....+ Rn
3) I total = IR1 = IR2 = IR3 ....=IRn

Ohm's Law can also be used to find unknown values of V, I and R in a series circuit.

Although there are many important rules that govern series circuits, there are other circuit characteristics that can be found. These are relationships that are formed by V, I and R in Ohm's Law. They're called Inverse and Direct relationships. First, Inverse relationships:

Assuming that the applied voltage remains constant:

* If resistance in a series circuit INCREASES--- then current flowing in the circuit will DECREASE.

* If the current in a series circuit INCREASES--- then the resistance DECREASES.

The same would be true if each of those two statements were reversed:

* If resistance in a series circuit DECREASES--- then current flowing in the circuit will INCREASE.

* If the current in a series circuit DECREASES--- then resistance INCREASES.

Figure A 7.1-4 shows how an Inverse relationship works.

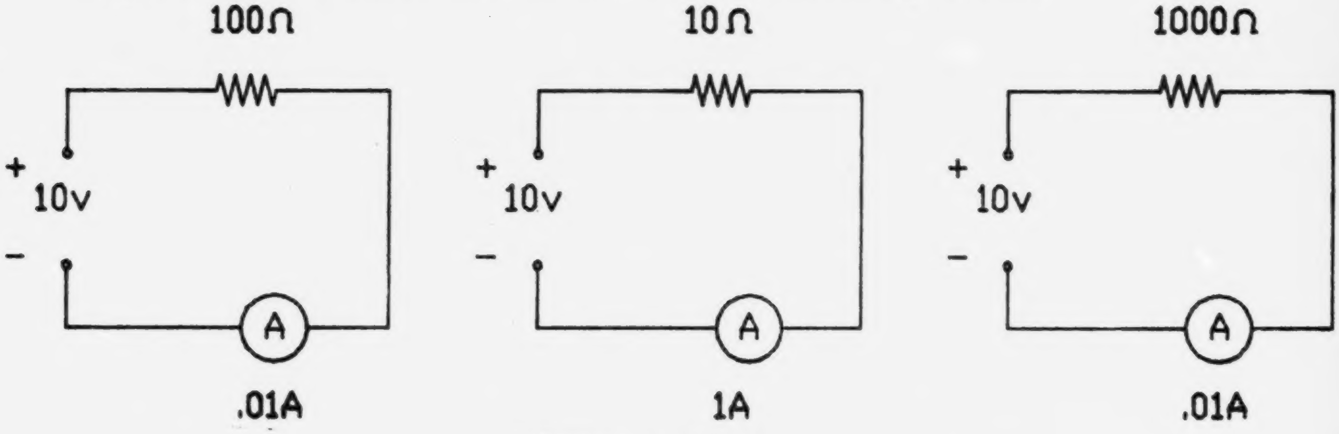


Figure A 7.1-4

In a Direct relationship, changes in applied voltage will cause a change in either current, or resistance, but NOT both. Here are some examples:

* If the applied voltage INCREASES--- the resistance INCREASES (assuming current stays the same).

* If the applied voltage INCREASES--- the current INCREASES (assuming resistance stays the same).

Figure A 7.1-5 shows an example of a Direct relationship.

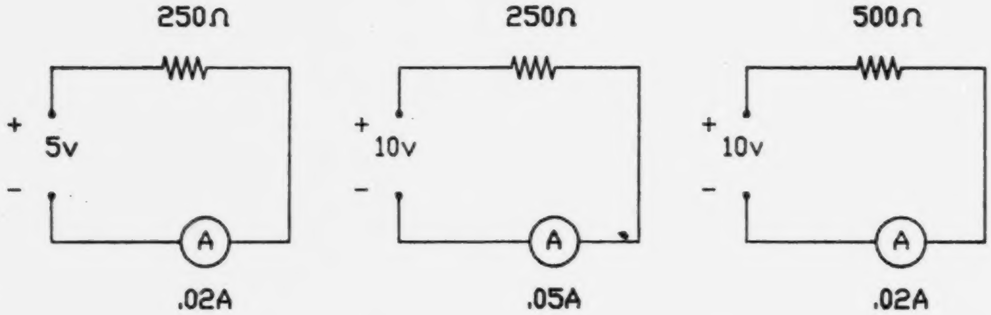


Figure A 7.1-5

Generally, electronic equipment relies on a constant voltage for power. Resistors are then used to control the amount of current flowing in the circuit. Resistors also "divide" the applied voltage according to the resistance in the series circuit. (Later you will examine VOLTAGE DIVIDERS in another learning guide).

Until now we've assumed that all the series circuits mentioned are complete circuits. But, if a series circuit contains an "open" or a break in it, then the source voltage will appear at the point of the break, and there will be NO voltage drops across the resistances in the circuit. Using a voltmeter you can locate the origin of the "open" by using the technique just mentioned. Analyze Figure A 7.1-6.

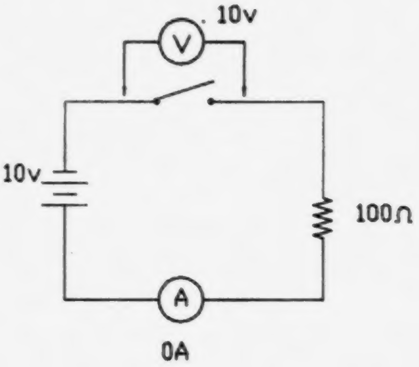


Figure A 7.1-6

INFORMATION SHEET A 7.1 CONT'D.

When a "short" occurs in a DC series circuit across a power source, there is very little resistance and very high current flow in the circuit. The only resistance in the circuit is the resistance of the connecting wires. If there is a "short" across an individual resistor in the circuit, the current will then increase. Why? Because now there is less resistance in the circuit (Inverse relationship). To locate a "short" across a resistor, use the voltmeter. If the voltmeter shows NO voltage drop directly across the resistor, you've found the "short." Figure A 7.1-7 shows an example of a "short."

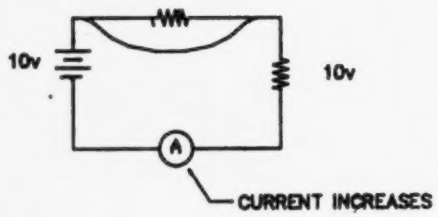


Figure A 7.1-7

Series circuits are one of three common circuit configurations used in electronic circuitry. They "divide" the applied voltage among resistances in the circuit, while keeping the current at the same value.

In order to understand this information more thoroughly, continue on with this task by referring back to the LEARNING STEPS portion of this guide.

ACTIVITY SHEET

A 7.2

SERIES CIRCUITS

DIRECTIONS: Complete each question. DO NOT CONTINUE with any portion of this guide until the Activity Sheet has been completed. If you need any help, see your instructor.

1. Define a series circuit:

2. Describe how current flows in a series circuit:

3. Discuss voltage characteristics in a series circuit:

4. What is a Direct relationship?

5. Define Inverse relationship:

6. Give Kirchhoff's Voltage Law in mathematical terms:

ACTIVITY SHEET A 7.2 CONT'D.

7. What happens when there is an "open" in a series circuit? (Your answer should be in terms of voltage and current.)

8. What is the total resistance of this circuit? See Figure A 7.2-1.

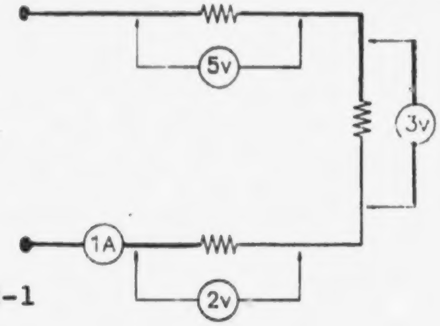


Figure A 7.2-1

R total = ______________________________

9. What happens in a series circuit if a "short" develops across a resistor?

10. Solve: See Figure A 7.2-2

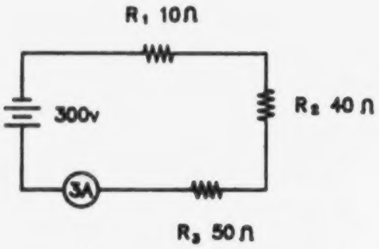


Figure A 7.2-2

R_{total} = ______________

V_{R1} = ______________

V_{R2} = ______________

V_{R3} = ______________

ACTIVITY SHEET A 7.2

ANSWER KEY

1. A circuit that has only one path for current to flow.

2. A circuit in which the total current is flowing through each component in the circuit.

3. Voltage in a series circuit will be divided among the resistances in the circuit so that the sum of the individual voltage drops will equal the total voltage applied in the circuit.

4. In a direct relationship, changes in the applied voltage will cause a corresponding change either in current or in resistance, but never in both at the same time.

5. An inverse relationship occurs between current and resistance in a series circuit. When either current or resistance increases, then the other decreases. Also, when either current or resistance decreases, then the other increases. All this is true when the applied voltage is kept constant.

6. V total = VR1 + VR2 + VR3 . . . + VRn

7. If an "open" occurs in a series circuit, then all current flow stops in the circuit. The source voltage will be at the point of the "open" in the circuit.

8. 10Ω

9. If a "short" develops across a resistor in a series circuit, then the current bypasses that resistance. There is little or no voltage present across that particular resistor. The circuit current increases because of the inverse relationship between the resistor and current in the circuit. Too high current flow could cause damage to the circuit.

10. R total = 100 Ω
    VR1 = 30V
    VR2 = 120V
    VR3 = 150V

ACTIVITY SHEET

A 7.3

SERIES CIRCUIT PROBLEMS

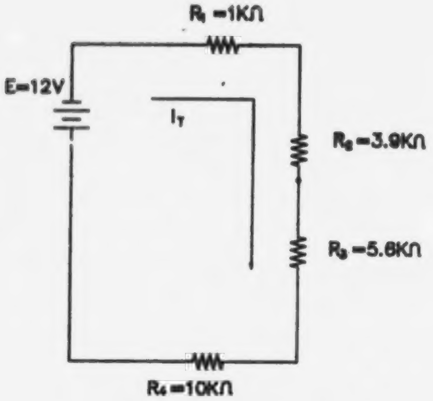

R_1 =1KΩ
E=12V
I_T
R_2=3.9KΩ
R_3=5.6KΩ
R_4=10KΩ

Figure 7.3-1

Refer to Figure 7.3-1 to answer the question below.

1. What is the total resistance of the circuit?
2. What amount of current will flow in the circuit?
3. How much voltage will be dropped across resistor R_3?
4. How much power will resistor R_4 have to dissipate?
5. What is the total power dissipated by the circuit?

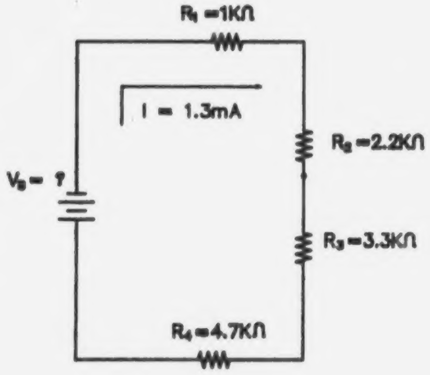

R_1 =1KΩ
I = 1.3mA
R_2=2.2KΩ
V_s= ?
R_3=3.3KΩ
R_4=4.7KΩ

Figure 7.3-2

ACTIVITY SHEET A 7.3 CONT'D.

Refer to Figure 7.3-2 to answer the questions below.

6. The voltage Vs is equal to what value?

7. The voltage loss from point A to point A would be what value?

8. If resistor R_4 is a 1/8 WAH resistor, is its wattage value great enough?

Refer to Figure 7.3-3 to answer the questions below.

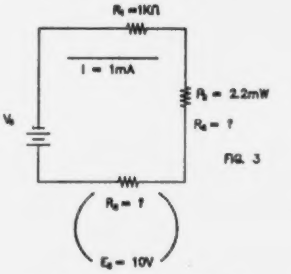


Figure 7.3-3

9. The total circuit resistance for Figure 7.3-3 is how many ohms?

10. What is the value of supply voltage needed?

ACTIVITY SHEET A 7.3

ANSWER KEY

1. $R_T = R_1 + R_2 + R_3 + R_4 = 1K\Omega + 3.9K\Omega + 5.6K\Omega + 10K\Omega$
$= 20.5K\Omega$

2. $I_T = E/R_T = 12V/20.5K\Omega = .585\ mA$

3. $E_3 = I_T \times R_3 = .585mA \times 5.6K\Omega = 3.27$ Volts

4. $P_4 = I_T^2 \times R_4 = .585mA^2 \times 10K\Omega = 3.43mW$

5. $P_T = E \times I_t = 12 \times .585mA = 7.02mW$

6. $V_s = R_T \times I_t$ Find RT.

$R_T = R_1 + R_2 + R_3 + R_4 = 1K\Omega + 2.2K\Omega + 3.3K\Omega + 4.7K\Omega$
$= 11.2K\Omega$

$V_S = 11.2K\Omega \times 1.3mA = 14.56$ volts

7. VAA = Voltage drop across R_2 & R_3

$E_2 = I_T \times R_2 = 1.3mA \times 2.2K\Omega = 2.86V$

$E_3 = I_T \times R_3 = 1.3mA \times 3.3K\Omega = 4.29V$

$VAA = E_2 + E_3 = 2.86 + 4.29 = 7.15$ Volts

8. $P_4 = I_T^2 \times R_4 = 1.3mA^2 \times 4.7K\Omega = 7.94mW$

1/8 watt = 125mW yes more than enough.

9. Must find R_2 & R_3 $R_2 = \frac{P_2}{1^2} = R_2 = 2.2mW/1mA^2 = 2.2K\Omega$

$R_3 = \frac{E_3}{I_T}$ $R_3 = \frac{10\ v}{1mA} = 10K\Omega$

$R_T = R_1 + R_2 + R_3 = 1K + 2.2K + 10K = 13.2K\Omega$

10. $Vs = I_T \times R_T$ $V_S = 1mA \times 13.2K\Omega = 13.2$ Volts

PROGRAM: ELECTRONICS

TASK: SERIES CIRCUITS

TASK #: A 7.4

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

ANALYZE, CONSTRUCT, AND TROUBLESHOOT BASIC SERIES RESISTIVE CIRCUITS USING OHM'S LAW AND KIRCHHOFF'S LAW.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

SERIES CIRCUITS

A 7.4

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
* 1.	Was the circuit wired according to the schematic?	Y	N
* 2.	Does the circuit function properly?	Y	N
3.	Was necessary data recorded?	Y	N
4.	Was the correct equipment used?	Y	N
* 5.	Was the equipment used correctly?	Y	N
* 6.	Were safety precautions followed?	Y	N
7.	Was the equipment returned to proper storage area?	Y	N

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

STUDENT'S SCORE ____

SERIES CIRCUITS

EXAM

A 7.5

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Series Circuits. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer a minimum of 8 out of 10 items correctly, 80%.

SERIES CIRCUITS

EXAM

A 7.5

1. Current in a series circuit has _____ value at any point in the circuit.

   A. the same
   B. a different
   C. an unequal
   D. an inverse

2. What voltage does a 100 - ohm resistor have across it when 2 amperes of current flow in a series circuit?

   A. 20.0 volts
   B. 13.2 volts
   C. 200 volts
   D. 150 volts

3. Kirchhoff's Voltage Law is

   A. V total = VR1=VR2=VR3 . . . =VRn
   B. V total = VR1 + VR2 + VR3 + ...+VRn
   C. V total = VR1 - VR2 - VR3 + ...+VRn
   D. V total = IR1 = IR2 = IR3 = ...=IRn

4. In any series circuit containing two or more resistors and a constant DC power source, when any one of the resistors is increased, the current ___________.

   A. increases
   B. decreases
   C. not be affected
   D. will always decrease .1 mA

5. Calculate the total resistance of the series circuit, Figure A 7.5-1, R total = ?

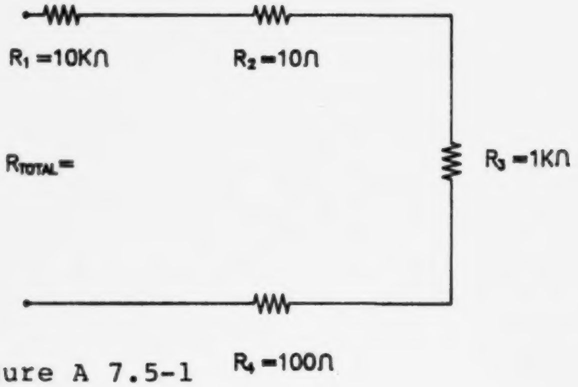


Figure A 7.5-1

A. 11 k
B. 1111 k
C. 10111 k
D. 11110 ohms

6. The circuit given, Figure A 7.5-2, is an example of a(n) ______________ circuit.

A. open
B. short
C. direct
D. indirect

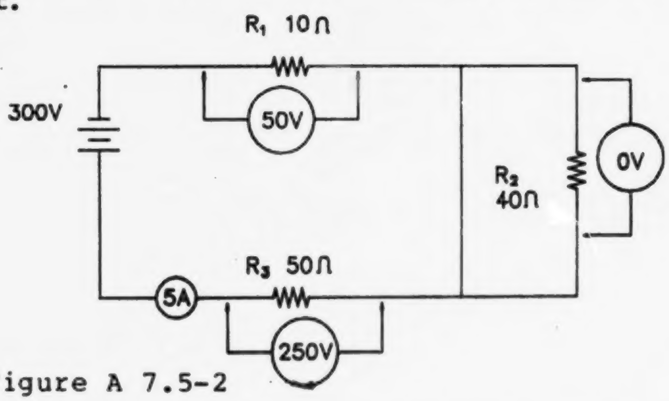

R₁ 10Ω
300V
50V
R₂
40Ω
0V
R₃ 50Ω
5A
250V

Figure A 7.5-2

7. The circuit given, Figure A 7.5-3 is an example of a(n) _______________ circuit.

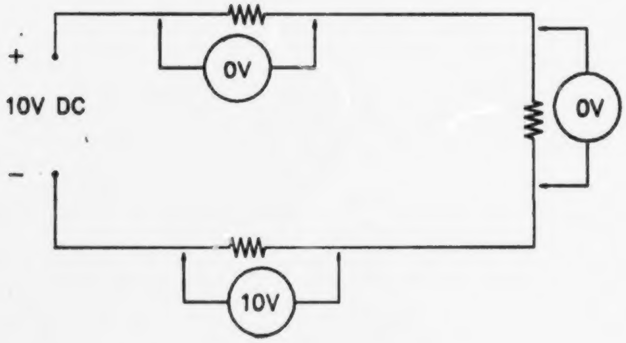

+
10V DC
−
0V
0V
10V

Figure A 7.5-3

A. short
B. direct
C. open
D. indirect

8. In any given series circuit containing two or more resistors, if one of the resistors is increased in value, the voltage drop across it will increase. This is known as ____________.

A. an inverse relationship
B. a short circuit
C. a loop
D. a direct relationship

9. Given the circuit, Figure A 7.5-4 solve for V total. V total = ?

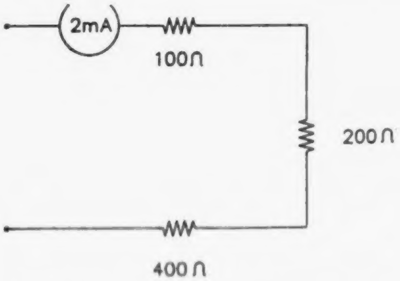


Figure A 7.5-4

A. 10.4v
B. 100v
C. 1.4v
D. .8v

10. A series circuit ____________________________________.

A. has only one voltage drop
B. has only two paths for current to flow
C. has one path for current to flow
D. has one path for voltage to flow

EXAM A 7.5

ANSWER KEY

1. A
2. C
3. B
4. B
5. D
6. B
7. C
8. D
9. D
10. C

ELECTRONICS

ANALYZING DC CIRCUITS

A 8: PARALLEL CIRCUITS

TASK:	Analyze, construct, and troubleshoot parallel resistive circuits using Kirchhoff's Law and Ohm's Law.
PURPOSE:	A parallel circuit is one of the most basic types of circuit arrangements. Parallel circuits are commonly used in electronic circuitry because of their ability to divide current to a desired level. In this learning guide, you will discover some basic principles about parallel circuits that can be applied when troubleshooting parallel circuits.
OBJECTIVE:	Given access to all necessary tools and equipment, you will analyze, construct, and troubleshoot parallel resistive circuits using Kirchhoff's Law and Ohm's Law. To master this task you must score 80% on a written exam and performance checklist.

ESTIMATED CLASS TIME: 8 HOURS

PARALLEL CIRCUITS

LEARNING STEPS

A 8

READ:	Information Sheet A 8.1 on "Parallel Circuits."
READ:	Information on parallel circuits from the following resource list.
VIEW:	Audio/Visual material on parallel circuits. Contact your instructor.
COMPLETE:	Activity Sheet A 8.2 on "Parallel Circuits."
COMPLETE:	Activity Sheet A 8.3 on "Parallel Circuits Problems."
COMPLETE:	Lab Performance on parallel circuits. Contact your instructor for this lab.
COMPLETE:	Performance Checklist A 8.4. Contact your instructor.
REVIEW:	All material covered in this learning guide and information presented by your instructor.
COMPLETE:	Written Exam A 8.5. Contact your instructor.

PARALLEL CIRCUITS

RESOURCES

A 8

1. BASIC ELECTRICITY AND CIRCUIT CONCEPTS: VOL. 1, DC CIRCUITS, Oliva and Dale (Radio Shack: Texas Instrument Learning Center, 1979), 4th Edition. Chapter 1.

2. DC ELECTRONICS (Heathkit Educational Systems, 1984). Units I & II.

3. BASIC ELECTRONICS, Grob (McGraw-Hill, 1984). Chapter 1.

4. INTRODUCTION TO ELECTRICITY AND ELECTRONICS, Bell & Howell Schools (DeVry Institute of Technology, 1984). Chapter 1001.

5. INTRODUCTION TO INDUSTRIAL ELECTRICITY-ELECTRONICS (Oklahoma Trade and Industrial Education).

6. ELECTRONICS: PRINCIPLES AND APPLICATIONS, Badrkhan and Larky (South Western Pub.). Chapter 1.

7. ELECTRICITY ONE-SEVEN, Mileaf (Hayden). Chapter 1.

8. ELECTRONIC COMMUNICATION, Schrader (McGraw-Hill Pub. Co.). 5th Ed. Chapter 1.

INFORMATION SHEET

A 8.1

PARALLEL CIRCUITS

One type of electronic circuit arrangement used in electronics is called a parallel circuit. A parallel circuit has characteristics much different from those of a series circuit. Remember in a series circuit the current stayed the same value in all parts of the circuit, and the voltage drop across each resistance varied according to the individual resistance. In a parallel circuit, however, the current divides according to the resistance offered through each branch of the circuit, and the voltage drop across each branch resistance will be the same value.

Let's look at some rules and definitions for parallel circuits one at a time.

DEFINITION: PARALLEL CIRCUIT - A parallel circuit has two or more paths for current to flow through. Notice Figure A 8.1-1.

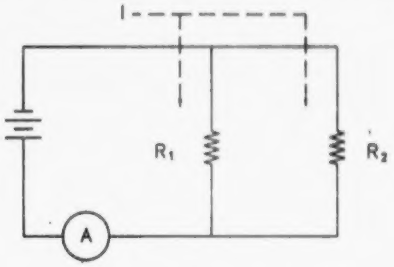


Figure A 8.1-1

DEFINITION: PARALLEL BANK - Two or more resistances grouped together in a parallel circuit.

DEFINITION: PARALLEL BRANCH - An individual path for current to flow within a parallel circuit.

DEFINITION: OPEN CIRCUIT - A circuit which does not provide a complete path for the flow of current.

DEFINITION: SHORT CIRCUIT - an abnormal connection of relatively low resistance between two points of a circuit. The result is a flow of excess (often damaging) current between these two points.

DEFINITION: KIRCHHOFF'S CURRENT LAW - The current flowing to a given point in a circuit is equal to the current flowing away from that point.

ABBREVIATIONS AND SYMBOLS AND FORMULAS:

E total = V total = The source voltage applied to the circuit. (Et or Vt) (NOTE: "E" and "V" both stand for voltage, and can be interchangeable for any formula).

I total = The total current flowing in the circuit. (I_t)

R total = The total resistance in the circuit. (R_t)

R_1 = Resistor #1, R_2 = Resistor #2, R_3 = Resistor #3, Rn = Infinite number of resistors.

IR_1, IR_2, IR_3, etc. can all be expressed as: "The current through R_1, R_2, R_3, and so on."

ER_1, ER_2, ER_3, (or) VR_1, VR_2, VR_3, etc. can all be expressed as: "The voltage dropped across R_1, R_2, R_3, and so on."

For 2 resistors in parallel: $$R \text{ total} = \frac{R_1 \times R_2}{R_1 + R_2}$$

For 3 or more in parallel : $$R \text{ total} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \;. \;. \;. + \frac{1}{R_n}}$$

GENERAL RULES:

1. The voltage across each branch of a parallel circuit is the same as the source voltage.
2. The total current in a parallel circuit is equal to the sum of the branch currents.
3. The total resistance in a parallel circuit (bank) is less than the resistance of any branch.
4. In a parallel circuit (bank), the current through each branch is inversely proportional to the resistance of the branch.

Let's look at these general rules one at a time.

Rule #1 simply means that if you have a parallel circuit with only one parallel bank, the source voltage will be present across each branch. Each resistance within that branch will have the same value of voltage. To illustrate this point, analyze Figure A 8.1-2.

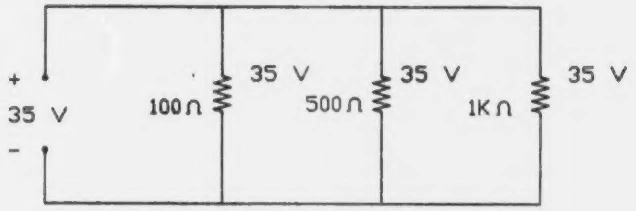


Figure A 8.1-2

Notice in the example that all voltage drops in the parallel circuit are equal. This will always be true.

Rule #2 states that the total current in a parallel circuit is equal to the sum of the branch currents (Kirchhoff's Law). If each resistance within the branch is different, then each resistance will have a different value of current flowing through it. We can then say; $IR_1 + IR_2 + IR_3 \ldots . + IR_n = I_t$ for each parallel branch in a given circuit.

As an example, if a parallel circuit had branch currents of 1 Amp, 3 Amps, and 6 Amps . . . what would the total amperage be in the circuit? If you guessed 10 Amps, you're correct. See Figure A 8.1-3

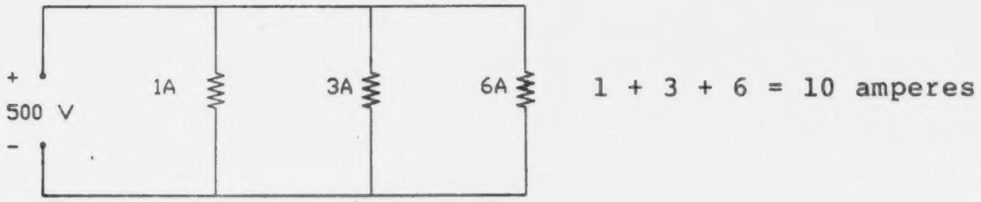


Figure A 8.1-3

Resistance in a parallel circuit is very different from resistance in a series circuit. In a series circuit, resistances were added together to find the total circuit resistance. In a parallel circuit, however, resistances are calculated in a different way. The third rule states that, the total resistance in a parallel circuit is less than the resistance of any branch, and can be expressed algebraically in several ways.

INFORMATION SHEET A 8.1 CONT'D.

When there are only two resistances in a parallel branch the formula to be used is:

$$R_t = \frac{R_1 \times R_2}{R_1 + R_2} \qquad \text{Product - Sum Formula}$$

Look at Figure A 8.1-4 to solve for two parallel resistances.

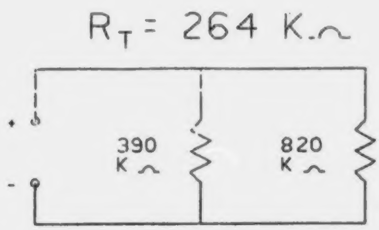


Figure A 8.1-4

Notice that the answer for the total resistance is less than the smallest resistance within that branch. This will ALWAYS be true for parallel circuits. Any answer larger than the smallest resistance tells you that there has been an error in calculating.

What about a parallel circuit that has more than two resistances within its branch? To solve for a parallel circuit that has more than two resistances, use this formula:

$$R_t = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ . \ . \ . \ \frac{1}{R_n}} \qquad \text{Reciprocal 1 Formula}$$

(*) There is a shortcut for finding the total resistance in parallel circuit, but the resistances in the circuit MUST ALL BE THE SAME VALUE. Here's the shortcut: Simply take the value of any one of the resistors in the parallel circuit (it doesn't matter which one since they're all the same), and divide that value by the total number of resistors that are in that parallel bank. Figure 8.1-5 show how this works.

$$\begin{array}{r} 11. \\ 3\overline{)\,33.} \end{array}$$

$R_t = 11\,\Omega$

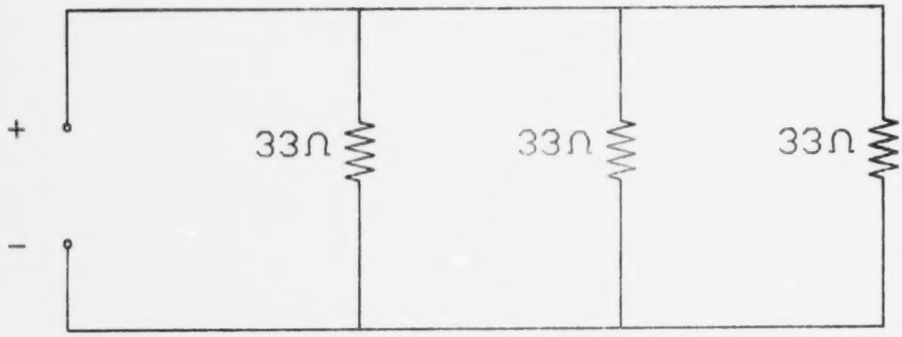


Figure A 8.1-5

The last general rule for parallel circuits states that in a parallel circuit, the current through each branch is inversely proportional to the resistance of the branch. Therefore, for a given branch circuit, $I = 1/R$ or $R = 1/I$.

In this learning guide, you've been introduced to some of the basic characteristics of parallel circuits. The information presented to you has been a generic overview on parallel circuits. For more information on parallel circuits, refer to the "Learning Steps" portion of this guide and/or your instructor.

ACTIVITY SHEET

A 8.2

PARALLEL CIRCUITS

DIRECTIONS: Complete each question. DO NOT CONTINUE with any portion of this guide until the Activity Sheet has been completed. If you need any help, see your instructor. Label all components and values.

1. Draw a parallel circuit that has: 12 volt battery, 1000 ohm, 7.2k ohm, and 500 ohm resistors.

2. A circuit which has 2 or more paths for current to flow is called a(n) __________________ circuit.

   A. linear
   B. series
   C. open
   D. parallel

3. The E total of a parallel circuit is _______________ across each branch of that circuit.

   A. zero
   B. different
   C. the same
   D. 1/R

4. State Kirchhoff's Current Law:

ACTIVITY SHEET A 8.2 CONT'D.

5. Given these resistances in parallel, find the total resistance offered in the circuit:

   R1 = 680 ohms
   R2 = 680 ohms

   R total = ______________________________

6. Given these resistances in parallel, find the total resistance of the circuit:

   R1 = 680 ohms
   R2 = 620 ohms
   R3 = 910 ohms

   R total = ______________________________

7. In the event there develops a "short" across one branch of a parallel circuit, how does that affect the other branches in that circuit?

8. Parallel circuits are sometimes referred to as ___________ dividers.

ACTIVITY SHEET A 8.2 CONT'D.

9. Draw a parallel circuit with these components and find the missing values:

Power source: 6 VDC

Resistors: R1 = 22 ohms, R2 = 68 ohms, R3 = 47 ohms

Find: R total = ____________________

I total = ____________________

IR 1 = ____________________

IR 2 = ____________________

IR 3 = ____________________

10. Given a parallel circuit with the following components, determine the resistance of R1:

Power source: 12 VDC

Resistors: R2 = 3 ohms

Current: I total = 10 amps

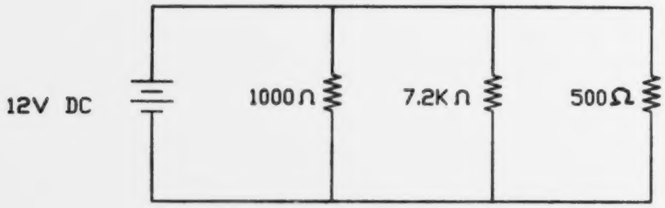
IR2 = 4 amps

Find: IR 1 = _____________

ACTIVITY SHEET A 8.2

ANSWER KEY

1.



2. D

3. C

4. Kirchhoff's Current Law: The current flowing to a given point in a circuit is equal to the current flowing away from that point.

(or)

I total = $IR_1 + IR_2 + IR_3 + \ldots IR_n$

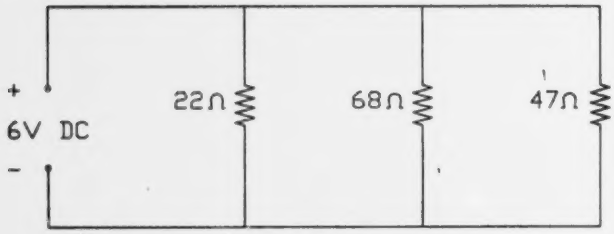
5. 340 ohms

6. 907 ohms

7. The other branch currents will remain "normal" or unaffected by the short.

8. current

9.



R total = ________12 ohms ________

I total = ________489 mA ________

IR_1 = ________273 mA ________

IR_2 = ________88 mA ________

IR_3 = ________128 mA ________

10. 2 ohms

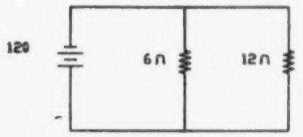
ACTIVITY SHEET

A 8.3

PARALLEL CIRCUIT PROBLEMS

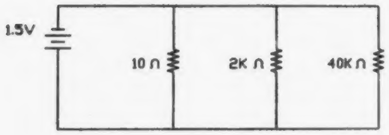
Find the total conductance and resistance for the following circuits.

1.



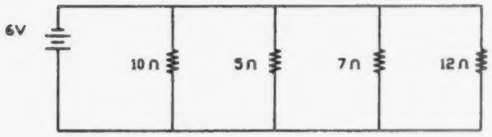
R_T ______ G_T ______

2.


1.5V
10Ω
2KΩ
40KΩ

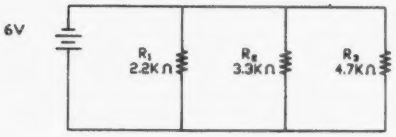
R_T ______ G_T ______

3.


6V
10Ω
5Ω
7Ω
12Ω

R_T ______ G_T ______

4.


6V
R_1 2.2KΩ
R_2 3.3KΩ
R_3 4.7KΩ

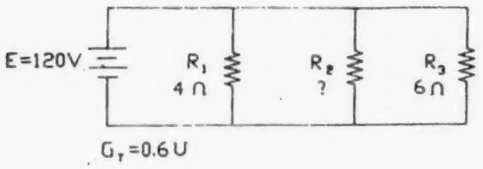
R_T ______ G_T ______

5. What is the total current for each of the above circuits?

(a)
(b)
(c)
(d)

ACTIVITY SHEET A 8.3 CONT'D.

6.

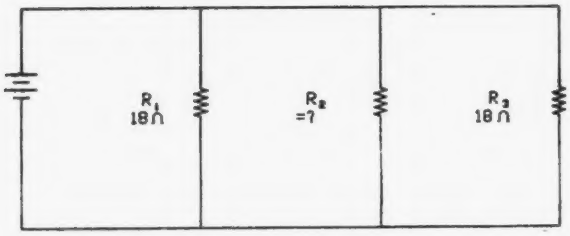

E=120V
R_1
4 Ω
R_2
?
R_3
6 Ω
G_T=0.6 ℧

What is the value of R for the circuit of Figure A 8.3-1.

R_2 =

GT = 0.6 Figure A 8.3-1

7.


R_1
18 Ω
R_2
=?
R_3
18 Ω

Find the value of R_2.

8. How much current flows in the circuit above?

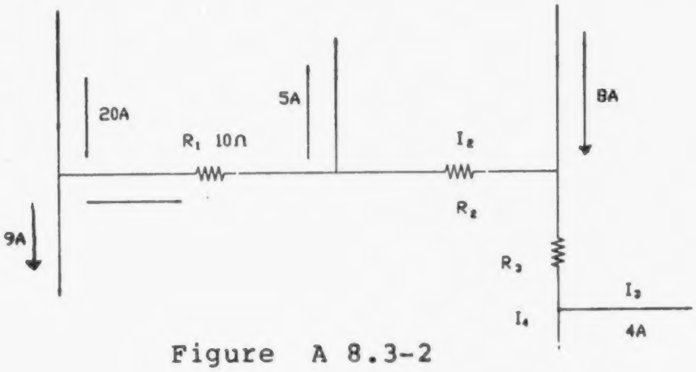

20A
R_1 10 Ω
5A
I_2
8A
R_2
9A
R_3
I_3
I_4
4A

Figure A 8.3-2

9. What is the voltage loss or drop across R_1?

10. How much current flows through R_3?

ACTIVITY SHEET A 8.3

ANSWER SHEET

1. $$R_T = \frac{R_1 \times R_2}{R_1 + R_2} = R_T = \frac{6\Omega \quad \times 12\Omega}{6\Omega \quad + 12\Omega} = \frac{72\,\Omega}{18\,\Omega}$$

$$= 4\Omega \qquad G_T = \frac{1}{R_1} = \frac{1}{4} = .25$$

2. $$R_T = \frac{1}{\frac{1}{10\Omega} + \frac{1}{2K\Omega} + \frac{1}{40K\Omega}} = \frac{1}{.1 + .0005 + 2.5K \times 10^{-5}}$$

$$= \frac{1}{.1005} = 9.95\Omega$$

$$G_T = \frac{1}{R_T} = \frac{1}{9.95} = .1005$$

3. $$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4}} = \frac{1}{\frac{1}{10\Omega} + \frac{1}{5\Omega} + \frac{1}{7\Omega} + \frac{1}{12\Omega}} = 1.9\Omega$$

$$G_T = \frac{1}{R_T} = \frac{1}{1.9} = .526$$

4. $$R_T = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} = \frac{1}{\frac{1}{2.2K\Omega} + \frac{1}{3.3K\Omega} + \frac{1}{4.7K\Omega}} = 1{,}030\Omega$$

$$G_T = \frac{1}{R_T} = \frac{1}{1030}$$

$$G_T = .001$$

ACTIVITY SHEET A 8.3 CONT'D.

5. (a) $I_T = \frac{E_T}{R_T} \quad I_T = \frac{120V}{4\Omega} \quad I_T = 30\ A$

(b) $I_T = \frac{E_T}{R_T} = \frac{1.5V}{9.95\Omega} = .151\ A$

(c) $I_T = \frac{E_T}{R_T} = \frac{6V}{1.9\Omega} = 3.158\ A$

(d) $I_T = \frac{E_T}{R_T} = I_T = \frac{6V}{1,030\Omega} = 5.8\ mA$

6. $G_T = 0.6 \qquad R_T = \frac{1}{G_T} \quad R_T = \frac{1}{0.6} = R_T = 1.666$

$G_1 = \frac{1}{R_1} \quad G_1 = \frac{1}{4} = .25 \quad G_3 = \frac{1}{6} = .166$

$G_2 = G_T - (G_1 + G_3)$

$G_2 = 0.6 - (.25 + .166)$

$G_2 = 0.6 - (.416)$

$G_2 = .184$

$R_2 = \frac{1}{G_2} = \frac{1}{18.4} = 5.43\Omega$

ACTIVITY SHEET A 8.3 CONT'D.

7. R_1 in parallel with $R_3 = R_{Eq}$

18Ω in parallel with 18Ω = 9Ω

$$R_T = \frac{1}{\frac{1}{R_2} + \frac{1}{RE_q}} \qquad 6\Omega = \frac{1}{\frac{1}{R_2} + \frac{1}{9\Omega}} = 6\Omega\left(\frac{1}{R_2} + \frac{1}{9}\right) = 1$$

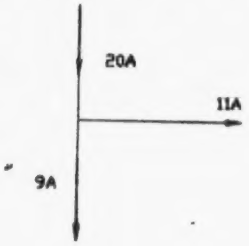
$$\frac{6}{1}\left(\frac{1}{R_2}\right) + 6\left(\frac{1}{9}\right) = 1 \qquad \frac{6}{R_2} + \frac{6}{9} = 1 \qquad \frac{6}{R_2} + \frac{2}{3} = 1$$

$$\frac{6}{R_2} = 1 - \frac{2}{3}$$

$$\frac{6}{R_2} = \frac{1}{3} \qquad \frac{1}{R_2} = \frac{1}{18} = R_2 = 18\Omega$$

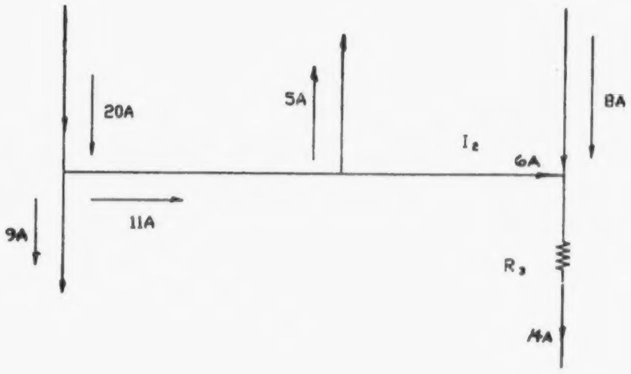
8. $I_T = \frac{E_T}{R_T} \qquad I_T = \frac{16\ V}{6} \qquad I_T = 2.66\ A$

9.



E = I x R
E + 11 A x 10Ω
E = 110 Volts

10. 14 A



PROGRAM: ELECTRONICS

TASK: PARALLEL CIRCUITS

TASK #: A 8.4

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

GIVEN ACCESS TO ALL NECESSARY TOOLS AND EQUIPMENT, ANALYZE, CONSTRUCT, AND TROUBLESHOOT PARALLEL RESISTIVE CIRCUITS USING KIRCHHOFF'S LAW AND OHM'S LAW.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out of 7 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

PARALLEL CIRCUITS

A 8.4

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the circuit wired according to the schematic?	Y N
2.	Does the circuit function properly?	Y N
*3.	Was necessary data recorded?	Y N
4.	Was the correct equipment used?	Y N
5.	Was the equipment used correctly?	Y N
6.	Were safety precautions followed?	Y N
*7.	Was the equipment returned to proper storage area?	Y N

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

STUDENT'S SCORE ____

PARALLEL CIRCUITS

EXAM

A 8.5

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Parallel Circuits. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer a minimum of 8 out of 10 items correctly, 80%.

PARALLEL CIRCUITS

EXAM

A 8.5

1. The voltage is the same across all branches of a parallel circuit.

   A. True
   B. False

2. When the total current in a parallel circuit is equal to the sum of the individual branch currents, it exemplifies Kirchhoff's Voltage Law.

   A. True
   B. False

3. For a parallel circuit, the voltage across any branch resistance is equal to the source voltage.

   A. True
   B. False

Use Figure A.8.5-1 to solve for questions 4 through 6

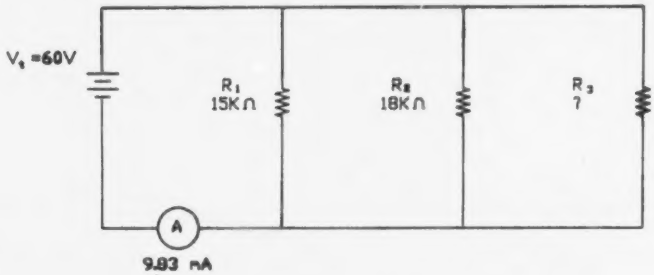


Figure A 8.5-1

4. The current flowing through R1 is ________.

   A. 10 mA
   B. 8 mA
   C. 4 mA
   D. 2 mA

5. The value of R3 is __________.

   A. 24k ohm
   B. 12k ohm
   C. 17k ohm
   D. 30k ohm

EXAM A 8.5 CONT'D.

6. The current flowing through R3 is _______.

   A. 4 mA
   B. 2.5 mA
   C. 13 mA
   D. 1.0 mA

7. If two resistors - 390K ohm and 820k ohm -were in parallel what would be their total resistance?

   A. 110k ohm
   B. 320k ohm
   C. 300 ohm
   D. 264k ohm

Use Figure A 8.5-2, to solve for questions 8 and 9

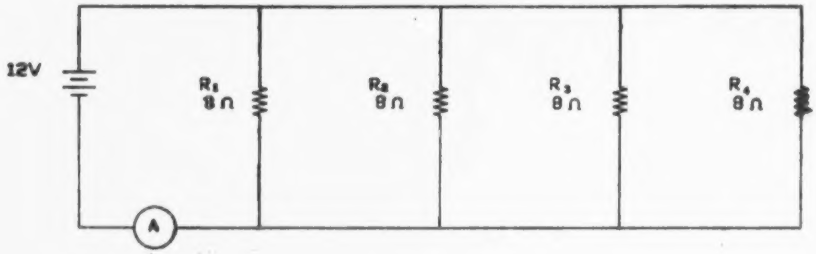


Figure A 8.5-2

8. What is the total circuit current?

   A. .4 A
   B. 1 A
   C. 6 A
   D. 3 A

9. What is the voltage drop across R4?

   A. 1 v
   B. 6 v
   C. 12 v
   D. 10 v

10. Adding a resistor in parallel with the source will ________.

   A. decrease the circuit current
   B. increase the circuit current
   C. not affect the circuit current
   D. not enough information given

EXAM A 8.5

ANSWER KEY

1. A
2. B
3. A
4. C
5. A
6. B
7. D
8. C
9. C
10. B

ELECTRONICS

ANALYZING DC CIRCUITS

A 9: SERIES-PARALLEL CIRCUITS

TASK:	Analyze, construct, and troubleshoot series-parallel resistive circuits using Kirchoff's Laws.
PURPOSE:	Most complex circuitry involves a combination of series and parallel circuits. Series-parallel circuits (also known as compound circuits) require a thorough understanding of basic series and parallel principles. In this learning guide, you will be introduced to many fundamental techniques used in analyzing and troubleshooting series-parallel circuits.
OBJECTIVE:	Given access to all necessary tools and equipment, you will analyze, construct, and troubleshoot series-parallel resistive circuits using Kirchoff's Laws.

ESTIMATED TIME: 4 HOURS

SERIES-PARALLEL CIRCUITS

LEARNING STEPS

A 9

READ: Information Sheet A 9.1, "Series-Parallel Circuits."

READ: Information on series-parallel circuits from the following resource list. See your instructor.

VIEW: Audio/Visual material on series-parallel circuits. Contact your instructor.

COMPLETE: Activity Sheet A 9.2, "Series-Parallel Circuits."

COMPLETE: Activity Sheet A 9.3, "Series-Parallel Circuits Problems."

COMPLETE: Lab Performance on series-parallel circuits. Contact your instructor for this lab.

COMPLETE: Performance Checklist A 9.4. Contact your instructor.

REVIEW: All material covered in this learning guide and information presented by your instructor.

COMPLETE: Written Exam A 9.5. Contact your instructor.

SERIES-PARALLEL CIRCUITS

RESOURCES

A 9

1. BASIC ELECTRICITY AND CIRCUIT CONCEPTS: VOL. 1, DC CIRCUITS, Oliva and Dale (Radio Shack: Texas Instrument Learning Center, 1979), 4th Edition. Chapter 1.
2. DC ELECTRONICS (Heathkit Educational Systems, 1984). Units I & II.
3. BASIC ELECTRONICS, Grob (McGraw-Hill, 1984). Chapter 1.
4. INTRODUCTION TO ELECTRICITY AND ELECTRONICS, Bell & Howell Schools (DeVry Institute of Technology, 1984). Chapter 1001.
5. INTRODUCTION TO INDUSTRIAL ELECTRICITY-ELECTRONICS (Oklahoma Trade and Industrial Education).
6. ELECTRONICS: PRINCIPLES AND APPLICATIONS, Badrkhan and Larky (South Western Pub.). Chapter 1.
7. ELECTRICITY ONE-SEVEN, Mileaf (Hayden). Chapter 1.
8. ELECTRONIC COMMUNICATION, Schrader (McGraw-Hill Pub. Co.). 5th Ed. Chapter 1.

INFORMATION SHEET

A 9.1

SERIES-PARALLEL CIRCUITS

There are many circuit configurations that involve resistors in series and in parallel. Applying basic principles involved in series and in parallel circuits should make it possible to solve most circuit problems. It should be noted again; 1) all components connected in series have the same current flowing through them; 2) all parts connected in parallel have the same voltage across them.

To reduce any series-parallel circuit to a single representative resistance, start with the components farthest from the power source. By gradually computing series and parallel resistances, the once complex circuit can be reduced to a simple series circuit that has only one resistance. Once the total resistance offered in the circuit is found, and knowing the applied voltage, the circuit can be found by using Ohm's Law.

In order to understand the correct procedure for simplifying a series-parallel circuit follow these steps:

1) Analyze the circuit to determine parallel and series portions of the circuit. See Figure A 9.1-1.

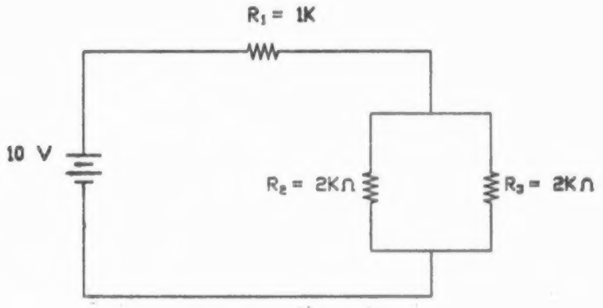


Figure A 9.1-1

R_1 is a series resistor. R_2 and R_3 form a parallel branch.

2) Simplify any parallel branch resistances, beginning farthest away from the power source (in this case there is only one parallel branch). See Figure A 9.1-2.

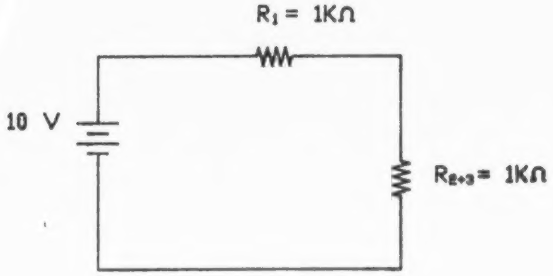


Figure A 9.1-2

3) Once the circuit has been simplified to a single circuit, solve for the total resistance in the circuit. See Figure A 9.1-3.

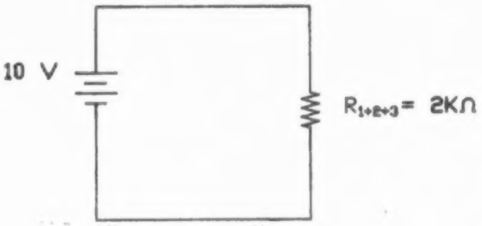


Figure A 9.1-3

4) Since R_{total} = 2k and there is a 10v power source, Ohm's Law can be used to find the total current in the circuit.

$$I_{total} = \frac{E_{total}}{R_{total}} = \frac{10v}{2k\Omega} = .005A \text{ or } 5mA$$

Even though our example involves a rather simple series-parallel circuit, even the most complex circuits can be easily simplified by following the general rules for series circuits and parallel circuits.

The information presented here has not covered all the material involved with analyzing, constructing, and troubleshooting series-parallel circuits. To learn more about complex circuits, continue on with this learning guide.

ACTIVITY SHEET

A 9.2

SERIES-PARALLEL CIRCUITS

DIRECTIONS: Complete each question. DO NOT CONTINUE with any portion of this guide until the Activity Sheet has been completed. If you need any help, see your instructor.

1) **Find R_{eq}** See Figure A 9.2-1

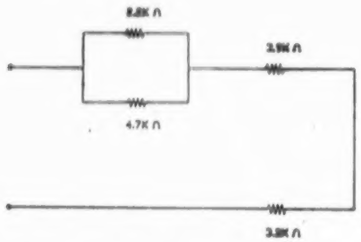

6.8K Ω
3.9K Ω
4.7K Ω
3.3K Ω

Figure A 9.2-1

R_{eq} =

2) **See Figure A 9.2-2**

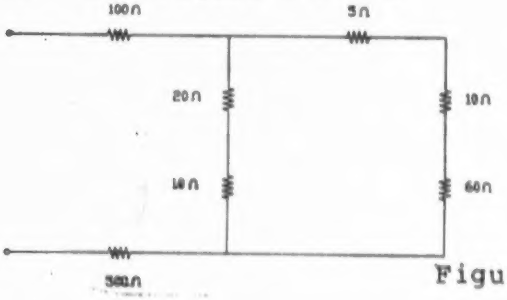

100 Ω
5 Ω
20 Ω
10 Ω
10 Ω
60 Ω
300 Ω

Figure A 9.2-2

R_{eq} =

3) **See Figure A 9.2-3**

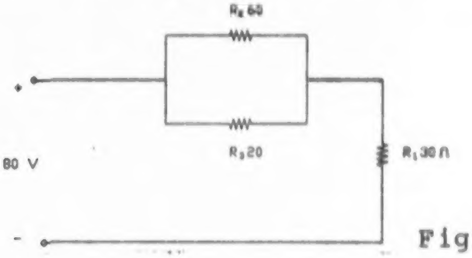

R₂ 60
+
R₃ 20
80 V
R₁ 30 Ω
-

Figure A 9.2-3

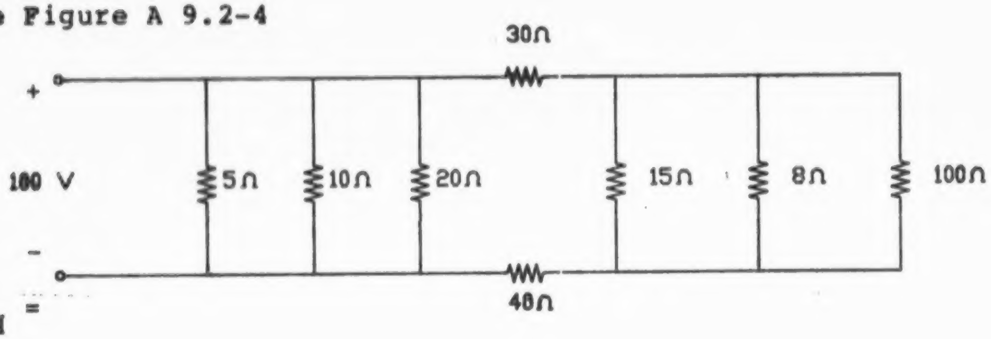
I_1 =

I_2 =

E_1 =

ACTIVITY SHEET A 9.2 CONT'D

4) See Figure A 9.2-4


30Ω
+
100 V
-
5Ω
10Ω
20Ω
15Ω
8Ω
100Ω
40Ω

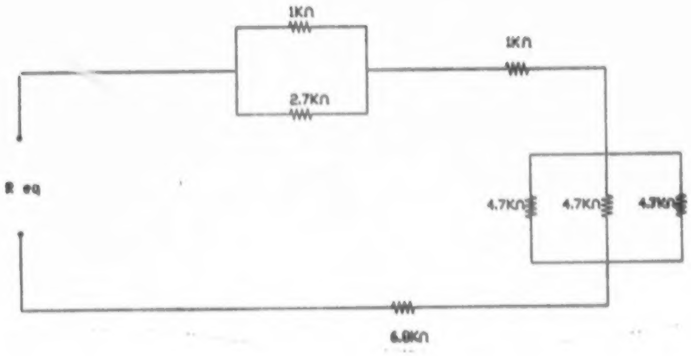
R_{eq} =

I_t =

Figure A 9.2-4

5) How is total resistance determined in a series-parallel circuit?

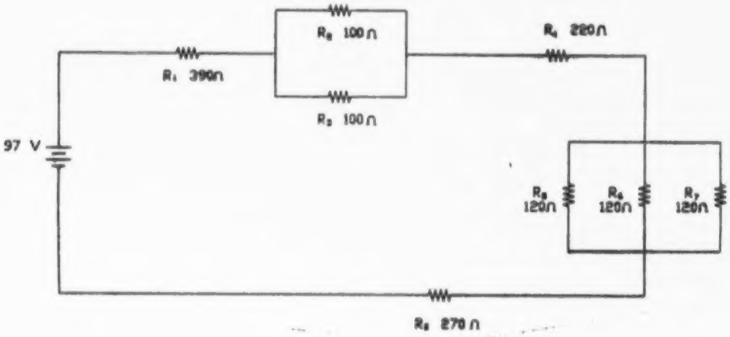
6) See Figure A 9.2-5


1KΩ
2.7KΩ
1KΩ
R eq
4.7KΩ
4.7KΩ
4.7KΩ
6.8KΩ

R_{Eq} =

Figure A 9.2-5

7) See Figure A 9.2-6


R_3 100Ω
R_4 220Ω
R_1 390Ω
R_2 100Ω
97 V
R_5 120Ω
R_6 120Ω
R_7 120Ω
R_8 270Ω

E_{R1} =

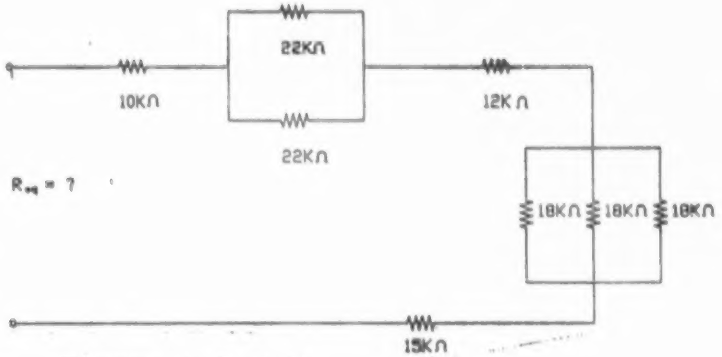
I_{R2} =

E_{R6} =

Figure A 9.2-6

8) A 200Ω resistor and a 300Ω resistor are in parallel. In series with them is a 180Ω resistor. The whole combination is across a 50V generator. What current flows through the generator?

9) See Figure A 9.2-7

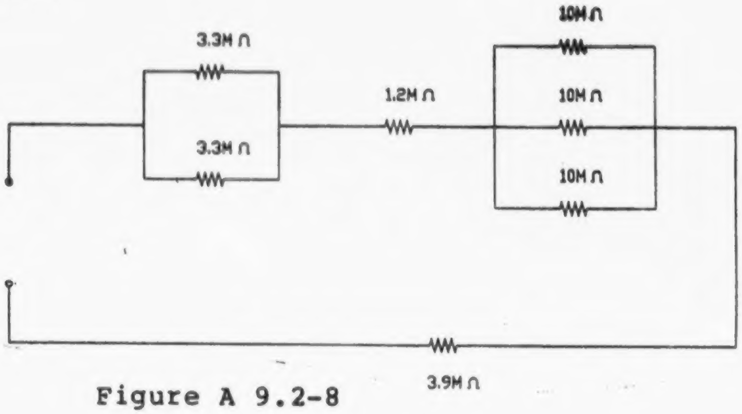

22KΩ
10KΩ
12KΩ
22KΩ
R_{eq} = ?
18KΩ
18KΩ
18KΩ
15KΩ

R_{eq} =

Figure A 9.2-7

ACTIVITY SHEET A 9.2 CONT'D

10) See Figure A 9.2-8


3.3M Ω
3.3M Ω
1.2M Ω
10M Ω
10M Ω
10M Ω
3.9M Ω

R_{eq} =

Figure A 9.2-8

ACTIVITY SHEET A 9.2

ANSWER SHEET

1) $R_t = 8.7\ k\Omega$

2) $R_{eg} = 621.4\ \Omega$

3) $I_1 = 1.78$ A $I_2 = .44$ A $E_1 = 53.4v$

4) $R_{eg} = 2.755\Omega$ $I_t = 36.3$ A

5) Simplify any parallel branches to one resistance. Solve for all series resistances to find one resistance.

6) $R_{eg} = 10.1\ k\Omega$

7) $E_{R1} = 39v$ $I_{R2} = 50$ mA $E_{R6} = 4.0$ v

8) I = .167 A or 167 mA

9) $R_{eg} = 54\ k\Omega$

10) $R_{eg} = 9.6\ M\Omega$

ACTIVITY SHEET

A 9.3

SERIES-PARALLEL CIRCUITS PROBLEMS

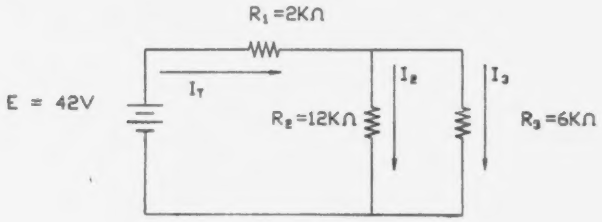

R₁=2KΩ
E = 42V
Iᴛ
R₂=12KΩ
I₂
I₃
R₃=6KΩ

Figure A 9.3-1

1. Find the total resistance of the circulation in Figure A 9.3-1.

2. What is the current marked I_2?

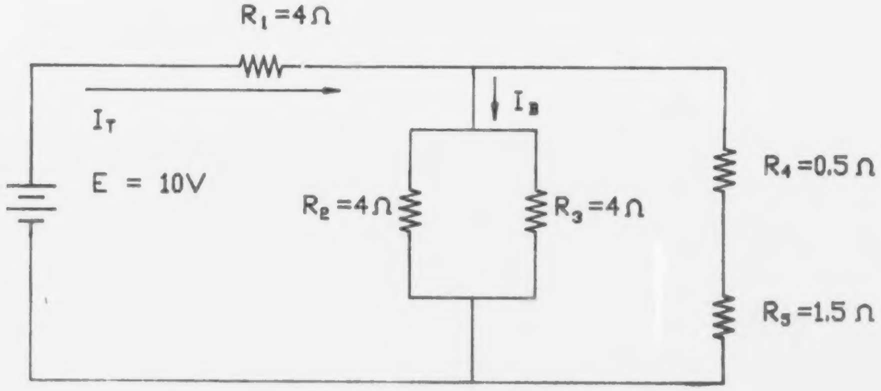

R₁=4Ω
Iᴛ
E = 10V
Iʙ
R₂=4Ω
R₃=4Ω
R₄=0.5Ω
R₅=1.5Ω

Figure A 9.3-2

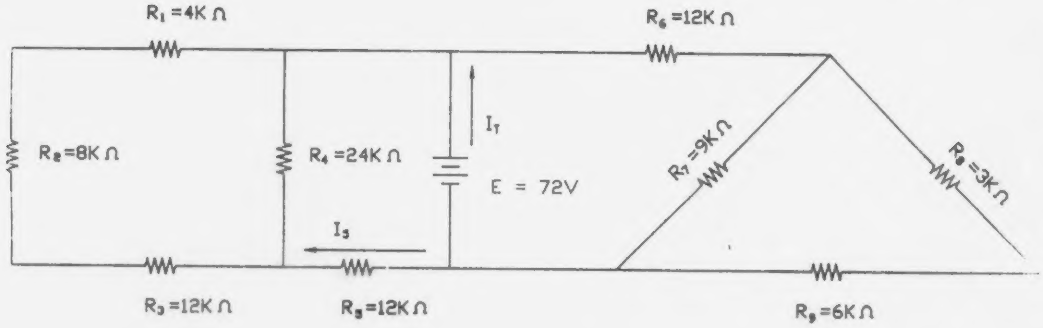
3. What is the total resistance of the circuit of Figure A 9.3-2.

4. What is the total current I_T?

5. What is the value of I_B?

6. What is the voltage drop across R_4?

ACTIVITY SHEET A 9.3 CONT'D.



R₁ =4K Ω
R₂=8K Ω
R₃ =12K Ω
R₄ =24K Ω
R₅ =12K Ω
R₆ =12K Ω
R₇ =9K Ω
R₈ =3K Ω
R₉ =6K Ω
I_T
I₅
E = 72V

Figure A 9.3-3

7. What is the total resistance of Figure A 9.3-3?

8. What is the current total, I_T?

9. How much current is flowing through register R_5?

10. What is the voltage drop across R_6?

ACTIVITY SHEET A 9.3

ANSWER SHEET

1. 12K//6K = 4KΩ 4K in series with R_1 2K = 6KΩ

   R_T = 6KΩ

2. Must first find voltage drop across R_1. $E_1 = I_T \times R_1$

   $I_T = \frac{E_T}{R_T} = \frac{42V}{6K\Omega} = 7\ mA$ $E_1 = 7\ mA \times 2K\Omega = 14$ volts

   Subtract this from source voltage (42 V) and you will have the branch voltage for I_2. 42 V - 14 V = 28 V

   Now, $I_2 = \frac{E_2}{R_2} = \frac{28\ V}{12\ K\Omega} = 2.33\ mA.$

3. $R_2//R_3 = 4\Omega//4\Omega = 2\Omega$ $R_4 + R_5 = 0.5\Omega + 1.5\Omega = 2\Omega$

   $(R_4 + R_5)//(R_2//R_3)$ $2\Omega//2\Omega = 1\Omega$

   $R_1 + (R_2//R_3)//(R_4 + R_5)$

   $R_T = 4\Omega + 1\Omega = 5\Omega$

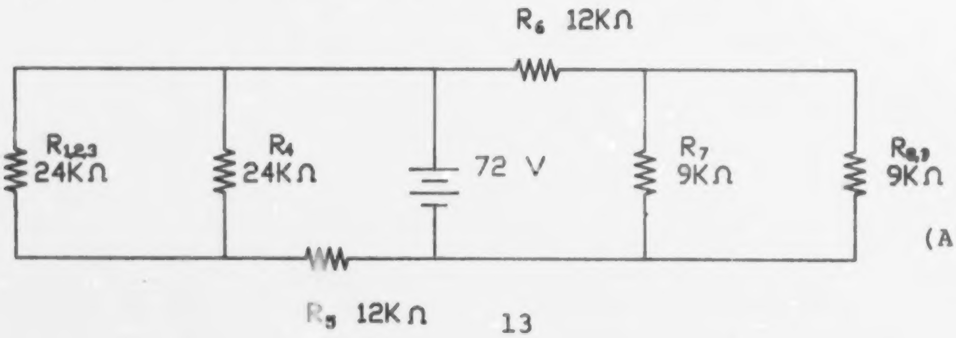
4. $I_T = \frac{E_T}{R_T} = I_T + \frac{10\ V}{5\ \Omega}$ $I_T = 2\ A$

5. Must find any series (main line drops) first. $E_1 = I_T \times R$. $E_1 = 2\ A \times 4\Omega$ $E_1 = 8\ V$ Subtract this from source voltage to get branch voltage V branch = E - E_1, 10 - 8 2 V Branch I_B resistance = 2 Ω $I_B = 2\ V/2\ \Omega = 1\ A$

6. Need branch current for R_4. Branch voltage same as I_B branch - 2 V $I_4 = 2/2$ 1 amp

   $E_4 = I_4 \times R_4 = 1\ A \times 0.5 = .5$ volts

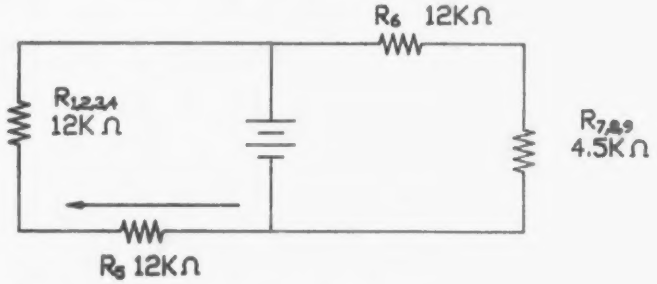
7. Redraw after combining series elements.



(A)

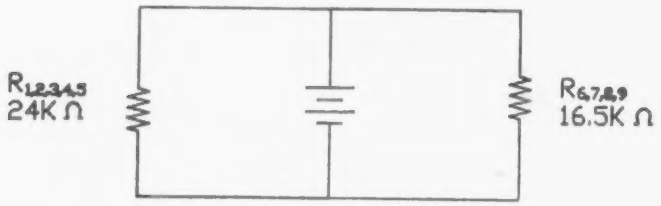
ACTIVITY SHEET A9.3 CONT'D.

Combine parallel elements and redraw.


R₆ 12KΩ
R1,2,3,4 12KΩ
R7,8,9 4.5KΩ
R5 12KΩ

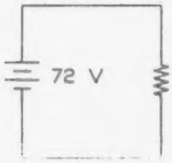
(B)

Combine series element and redraw.
(Repeat Step #1.)


R1,2,3,4,5 24KΩ
R6,7,8,9 16.5KΩ

(C)

Repeat Step #2



$R_{1,2,3,4,5,6,7,8, \& 9}$ $R_T = 9{,}778\ \Omega$

8. (D) $I_T = \dfrac{E_T}{R_T}$

$$I_T = \frac{72}{9{,}778\ \Omega} = 7.36\text{ mA}$$

9. Check drawings from question 7. Note 72 volts in drawing (B) is in parallel with R_5 $I_5 = 72\text{ V}/24\text{ K}\Omega$

$I_5 = 3\text{ mA}$

ACTIVITY SHEET A 9.3 CONT'D.

10. Check drawing (B) $I_6 = \frac{72\ V}{16.5\ K\Omega}$ $I_6 = 4.363$ mA

$E_6 = I_6 \times R_6 = E_6 = 4.363$ max 12K = 52.36 V

PROGRAM: ELECTRONICS

TASK: SERIES-PARALLEL CIRCUITS

TASK #: A 9.4

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

ANALYZE, CONSTRUCT, AND TROUBLESHOOT SERIES-PARALLEL RESISTIVE CIRCUITS USING KIRCHOFF'S LAW AND OHM'S LAW.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out 7 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

SERIES-PARALLEL CIRCUITS

A 9.4

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the circuit wired according to the schematic?	Y N
* 2.	Does the circuit function properly?	Y N
3.	Was necessary data recorded?	Y N
* 4.	Was the correct equipment used?	Y N
* 5.	Was the equipment used correctly?	Y N
* 6.	Were safety precautions followed?	Y N
7.	Was the equipment returned to proper storage area?	Y N

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

STUDENT'S SCORE ____

SERIES-PARALLEL CIRCUITS

EXAM

A 9.5

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Series-Parallel Circuits. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer correctly, 80%.

SERIES-PARALLEL CIRCUITS

EXAM

A 9.5

1. Match terms from the list which follows to their correct definitions. Write the correct numbers in the blanks.

____ a. Common point in a circuit

____ b. Difference of voltage

____ c. Components connecting end-to-end in a circuit to provide a single path for current flow

____ d. Abnormal, relatively low resistance connection between two points of a circuit

____ e. Resistance connected across a voltage source where only a portion of the voltage is tapped off

____ f. Connecting components both end-to-end and to the same terminals, combining both the series circuit and the parallel circuit

____ g. Circuit interruption that results in an incomplete path for current flow

____ h. Very sensitive meter for measuring small values of current, in both positive and negative directions

____ i. Determinant, such as voltage, frequency, and component values, of other characteristics of the circuit

____ j. Components connecting to the same pair of terminals so that current must take more than one path

____ k. Resistance connected to a voltage source which consumes power

____ 1. Instrument used to measure unknown resistance values

* * * * *

1. Series
2. Parallel
3. Series-parallel
4. Open
5. Voltage Divider
6. Load
7. Reference point
8. Parameter
9. Potential difference
10. Galvanometer
11. Wheatstone bridge
12. Short

2. Match abbreviations and symbols associated with series-parallel to their correct definitions. Write the correct numbers in the blanks.

____ a. Battery symbol

____ b. Resistor symbol

____ c. Total current

____ d. Equivalent resistance

____ e. Resistor voltage

____ f. Resistor; resistance

____ g. Ground

____ h. Kilo

____ i. Ohm

____ j. Alternating current

____ k. Voltage; volt

____ l. Ground symbol

____ m. Voltage applied

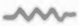
____ n. Total resistance

____ o. Resistor current

____ p. Current

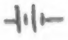
____ q. Kilohm

____ r. Number (of components)

1. A
2. V
3. AC
4. DC
5. N
6. Gnd
7. K
8. R
9. I
10. Kohm
11. E_R
12. I_R
13. R_t
14. R_e
15. I_t
16. E_a
17. Ω
18. 

EXAM A 9.5 CONT'D.

____ s. Direct current 19.

____ t. Amperage; amp 20. 

3. Distinguish between the characteristics of series circuits and parallel circuits. Write an "S" for each characteristic of a series circuit and a "P" for each characteristic of a parallel circuit.

____ a. Components are connected side-by-side in the same pair of terminals.

____ b. Current is equal throughout the circuit.

____ c. Voltage is equal through parallel branches.

____ d. All components are connected end-to-end.

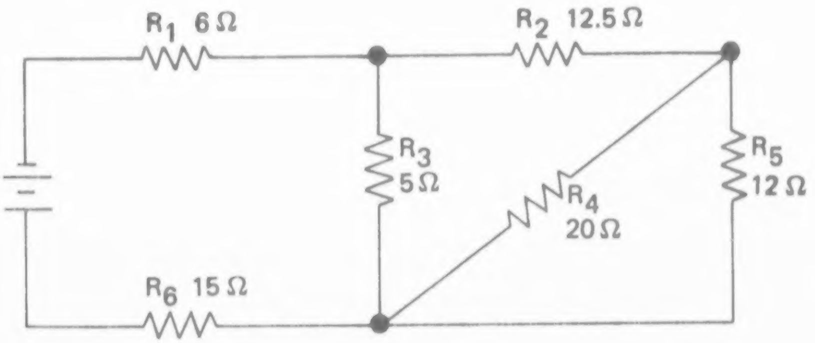
____ e. Total resistance is equal to the sum of all resistances.

____ f. Total resistance may be calculated using one of the resistance formulas for parallel circuits.

____ g. The sum of the individual voltage drops is equal to the voltage applied.

____ h. Current divides into each branch, depending upon the resistance.

4. Calculate total resistance in the following series-parallel circuit. See Figure A 9.5-1



R_t = ________________________________

Figure A 9.5-1

EXAM A 9.5 CONT'D.

5. Calculate current and voltage using Ohm's Law and Kirchoff's laws of voltage and current. See Figure A 9.5-2

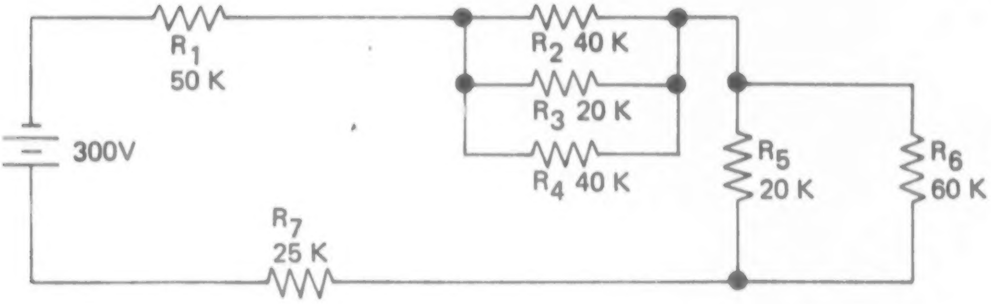

R1 50 K
R2 40 K
R3 20 K
R4 40 K
300V
R5 20 K
R6 60 K
R7 25 K

Figure A 9.5-2

a. R_t = ________________

b. I_t = ________________

c. I_{R1} = ________________

d. I_{R2} = ________________

e. I_{R3} = ________________

f. I_{R4} = ________________

g. I_{R5} = ________________

h. I_{R6} = ________________

i. E_{R1} = ________________

j. E_{R4} = ________________

k. E_{R5} = ________________

l. E_{R7} = ________________

6. Calculate voltages available in unloaded and loaded voltage dividers. See Figure A 9.5-3

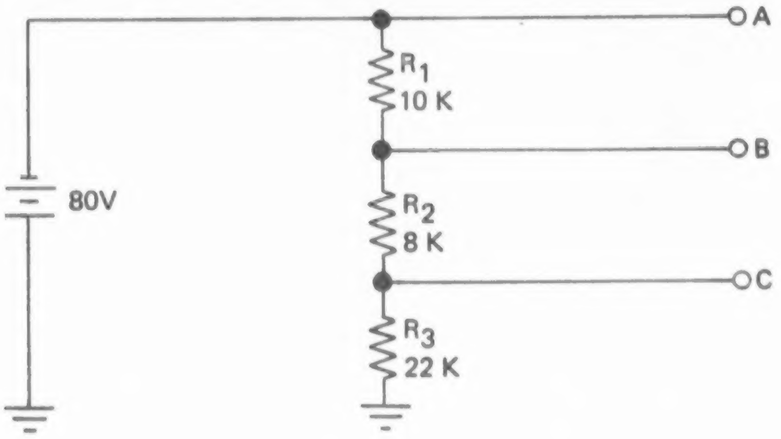

A
R1
10 K
B
80V
R2
8 K
C
R3
22 K

Figure A 9.5-3

a. 1) ________ Voltage at Point A with respect to Gnd

2) ________ Voltage at Point B with respect to Gnd

3) ________ Voltage at Point C with respect to Gnd

4) ________ Voltage at Point C with respect to Point A

5) ________ Voltage at Point B with respect to Point C

6) ________ Voltage at Point B with respect to Point A

See Figure A 9.5-4

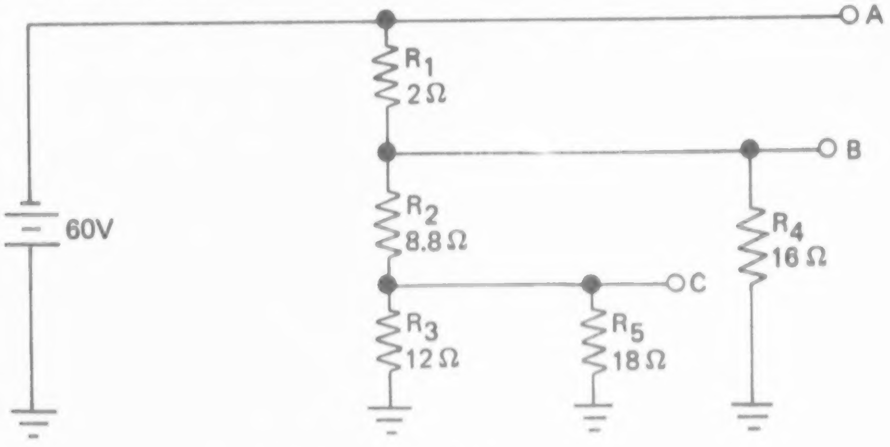

A
R1
2Ω
B
60V
R2
8.8Ω
R4
16Ω
C
R3
12Ω
R5
18Ω

Figure A 9.5-4

EXAM A 9.5 CONT'D.

b. 1. ________ Voltage at Point A with respect to Gnd

2. ________ Voltage at Point B with respect to Gnd

3. ________ Voltage at Point C with respect to Gnd

7. Determine circuit characteristics when components are open or shorted. Specify which components are open and which are shorted. See Figure A 9.5-5

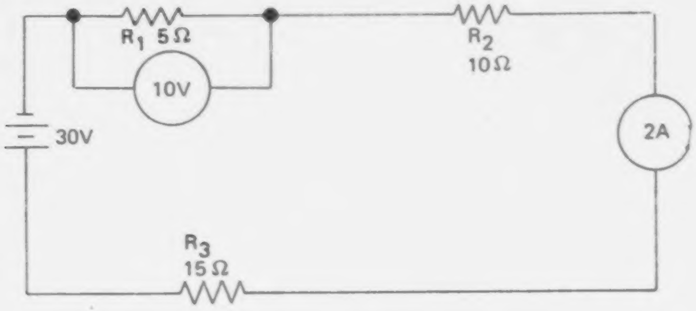

R_1 5Ω
10V
R_2 10Ω
30V
2A
R_3 15Ω

Figure A 9.5-5

a. ____

See Figure A 9.5-6

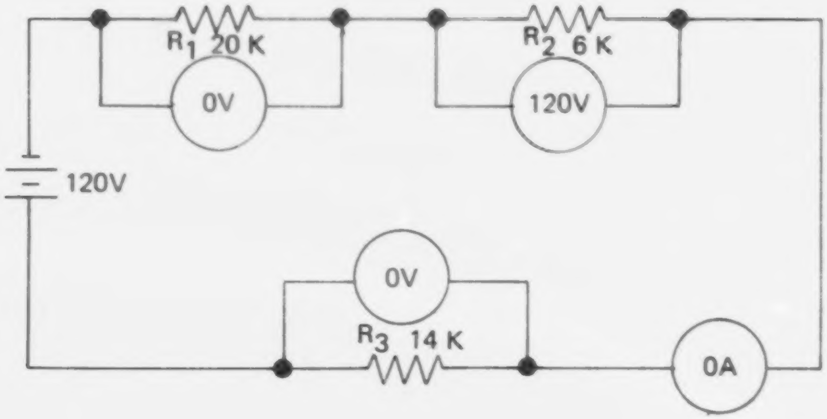

R_1 20 K
0V
R_2 6 K
120V
120V
0V
R_3 14 K
0A

Figure A 9.5-6

b. ____

See Figure A 9.5-7

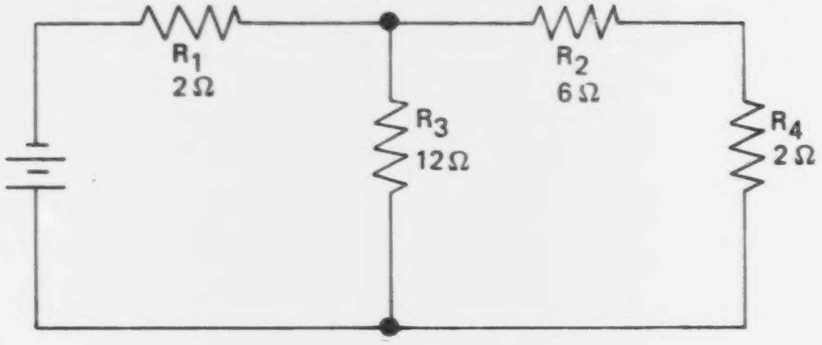
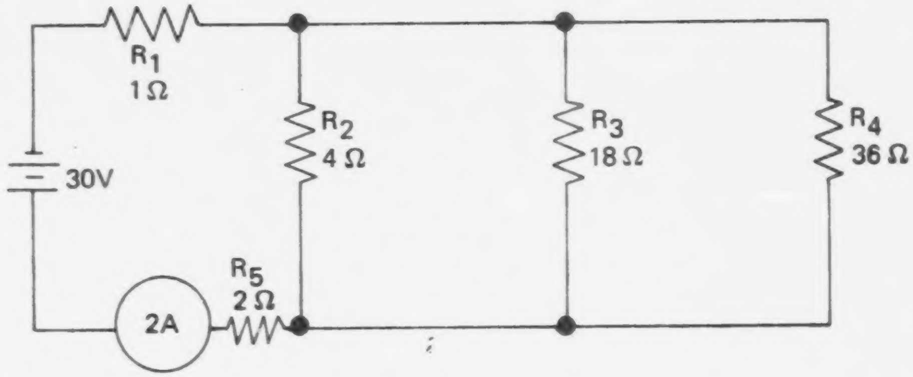

R1
2Ω
R2
6Ω
R3
12Ω
R4
2Ω

Figure A 9.5-7

c. ____

See Figure A 9.5-8


R1
1Ω
R2
4Ω
R3
18Ω
R4
36Ω
30V
R5
2Ω
2A

d. ____

Figure A 9.5-8

EXAM A 9.5

ANSWER KEY

1) a. 7
b. 9
c. 1
d. 12
e. 5
f. 3
g. 4
h. 10
i. 8
j. 2
k. 6
l. 11

2) a. 20
b. 18
c. 15
d. 14
e. 11
f. 8
g. 6
h. 7
i. 17
j. 3
k. 2
l. 19
m. 16
n. 13
o. 12
p. 9
q. 10
r. 5
s. 4
t. 1

3) a. P
b. S
c. P
d. S
e. S
f. P
g. S
h. P

4. 25

EXAM A 9.5 CONT'D.

ANSWER KEY

5) a. 100 K
b. 3 mA
c. 3 mA
d. .75 mA
e. 1.5 mA
f. .75 mA
g. 2.25 mA
h. .75 mA
i. 150 V
j. 30 V
k. 45 V
l. 75 V

6) a. 1) 80 V
2) 60V
3) 44 V
4) 36 V
5) 16 V
6) 20V
b. 1) 60 V
2) 48 V
3) 21.6 V

7) a. R_3 shorted
b. R_2 open
c. R_3 open
d. R_2 open

ELECTRONICS

ANALYZING DC CIRCUITS

A 10: VOLTAGE DIVIDERS

TASK: Analyze, construct, and troubleshoot resistive voltage dividers (loaded and unloaded) using Kirchoff's Law and Ohm's Law.

PURPOSE: The resistance voltage divider is a convenient and inexpensive way of providing a number of voltages from a single power source. Understanding how the input current and voltage distribution of the voltage divider changes as the load changes is an important concept related to voltage divider circuits. In this learning guide you will become familiar with voltage divider circuits.

OBJECTIVE: Given access to all necessary tools and equipment, you will analyze, construct, and troubleshoot resistive voltage dividers (loaded and unloaded) using Kirchoff's Law. To master this task you must achieve a score of 80% on a written exam.

ESTIMATED CLASS TIME: 4 HOURS

VOLTAGE DIVIDERS

LEARNING STEPS

A 10

READ:	Information Sheet A 10.1 on "Voltage Dividers."
READ:	Information on voltage dividers in one or more of the following resources. See your instructor.
VIEW:	Audio/visual material on voltage dividers. Contact your instructor.
COMPLETE:	Activity Sheet A 10.2 on "Voltage Dividers".
COMPLETE:	Activity Sheet A 10.3 on "Voltage Divider Problems."
COMPLETE:	Lab Performance on voltage dividers. Contact your instructor for this lab.
COMPLETE:	Performance Checklist A 10.4. Contact your instructor.
REVIEW:	All material covered in this learning guide and information presented by your instructor.
COMPLETE:	Written Exam A 10.5. Contact your instructor.

VOLTAGE DIVIDERS

RESOURCES

A 10

1. BASIC ELECTRICITY AND CIRCUIT CONCEPTS: VOL. 1, DC CIRCUITS, Oliva and Dale (Radio Shack: Texas Instrument Learning Center, 1979), 4th Edition. Chapter 1.
2. DC ELECTRONICS (Heathkit Educational Systems, 1984). Units I & II.
3. BASIC ELECTRONICS, Grob (McGraw-Hill, 1984). Chapter 1.
4. INTRODUCTION TO ELECTRICITY AND ELECTRONICS, Bell & Howell Schools (DeVry Institute of Technology, 1984). Chapter 1001.
5. INTRODUCTION TO INDUSTRIAL ELECTRICITY-ELECTRONICS (Oklahoma Trade and Industrial Education).
6. ELECTRONICS: PRINCIPLES AND APPLICATIONS, Badrkhan and Larky (South Western Pub.). Chapter 1.
7. ELECTRICITY ONE-SEVEN, Mileaf (Hayden). Chapter 1.
8. ELECTRONIC COMMUNICATION, Schrader (McGraw-Hill Pub. Co.). 5th Ed. Chapter 1.

INFORMATION SHEET

A 10.1

VOLTAGE DIVIDERS

In some applications it is necessary to have two different unregulated load voltages. A voltage-divider network of resistors can develop a lower voltage from the higher voltage of a power supply. Figure A 10.1-1 illustrates a voltage divider circuit that is unloaded.

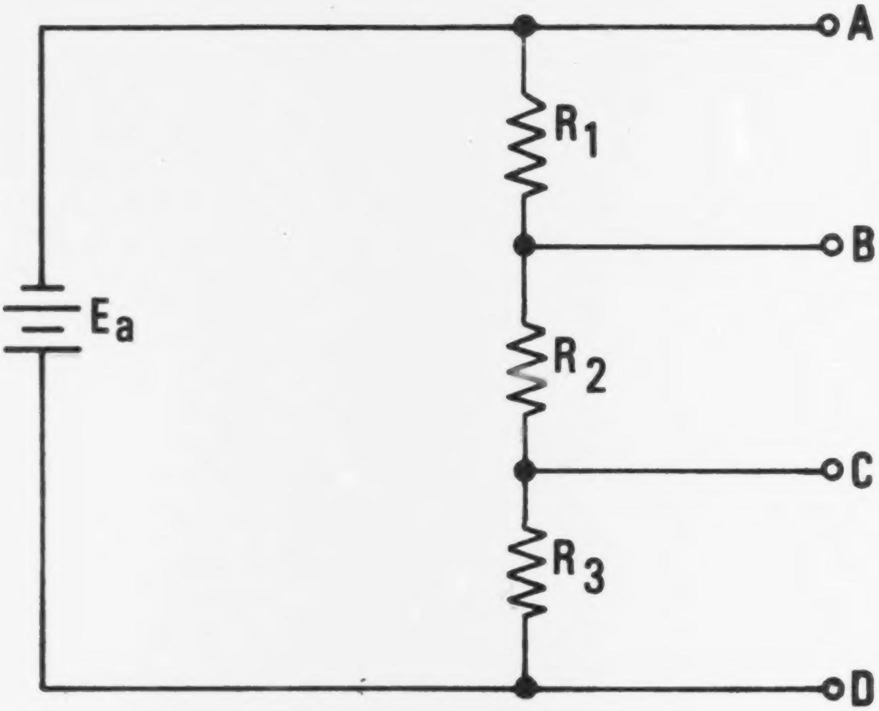


Figure A 10.1-1

Figure A 10.1-1 shows the same circuit as Figure A 10.1-2, but two loads (R_L) have been placed in parallel with resistors R_2 and R_3 to form a voltage divider circuit.

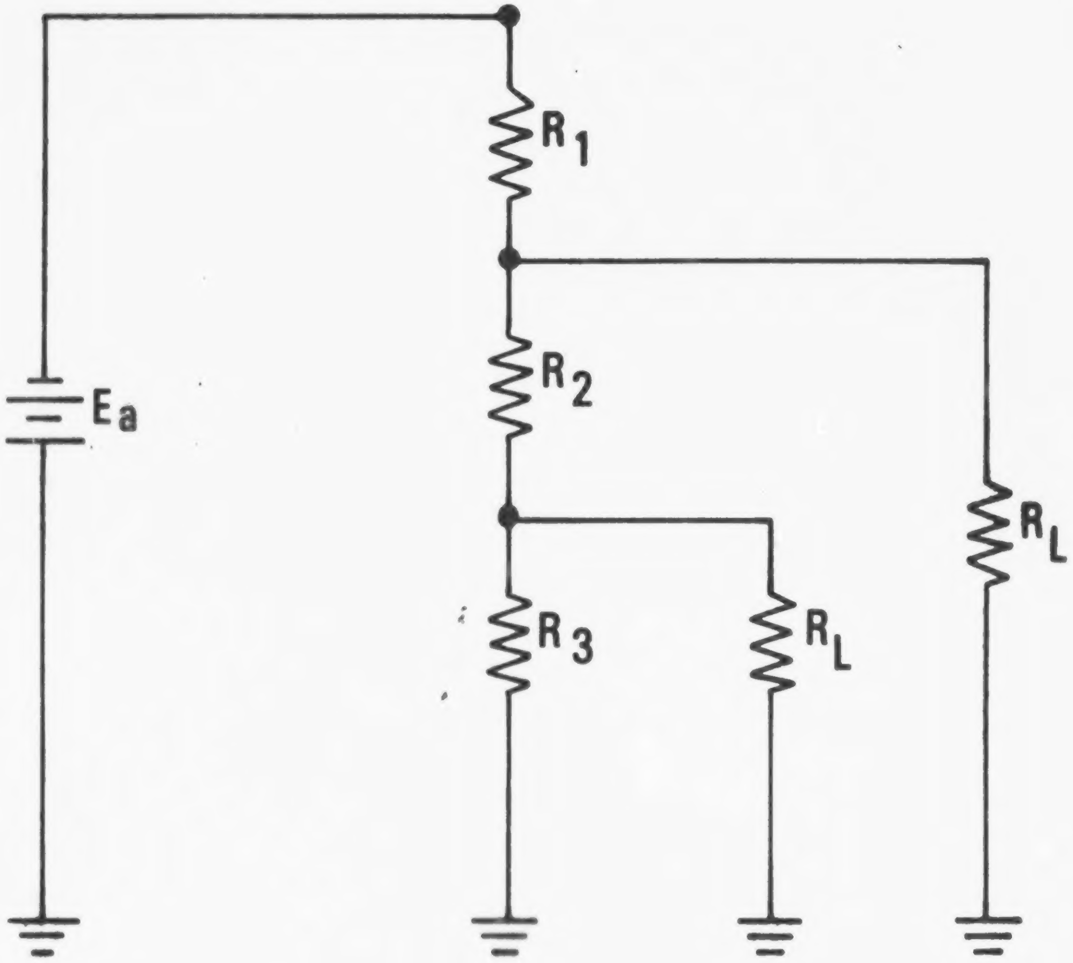


Figure A 10.1-2

In voltage divider circuits the "loading effect" can cause a significant problem for the power supply or circuit. As a rule of thumb a lower resistance draws a greater current and is therefore a greater load, while a higher resistance draws less current and is a lighter load.

Since there can be any number of load voltages needed in a circuit, a resistor must be placed in parallel with the load to help determine the load voltage. The "bleeder resistor" develops the voltage that is delivered to the load, and also functions to stabilize the voltage to the load. Generally, the bleeder resistor equals 10% of the total load current.

The higher the bleeder current, the more stable the load voltage will be if the load current should vary; however, the bleeder current causes wasted power, all of which must be dissipated through the bleeder resistor.

A voltage divider is really no more than a series-parallel circuit. There are two paths for current to flow through the parallel branch. Therefore, the sum of the branch currents equals the total current which flows through a series resistor.

In a series circuit, voltage across resistors divides in proportion to the resistance. When a load is added, the resistance of the load must be combined with that of the resistor it parallels.

Whenever a load is added in a parallel branch, the voltage drop for the basic series circuit changes.

When a voltage divider is being designed, here are some considerations:

1) Examine power supply and load requirements.
2) Select bleeder current.
3) Calculate bleeder current.
4) Calculate resistance of other divider resistor(s).

There is much more to learn about voltage divider circuits. Many other examples of voltage dividers can be found in the resource material available.

ACTIVITY SHEET

A 10.2

VOLTAGE DIVIDERS

Given the following problems, you will solve for each unknown circuit value.

A. See Figure A 10.2-1

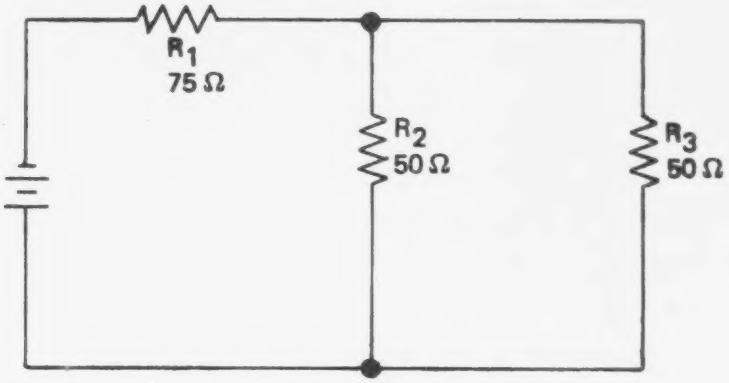

R_1
75 Ω
R_2
50 Ω
R_3
50 Ω

Figure A 10.2-1

R_{eq} = ____________________

B. See Figure A 10.2-2

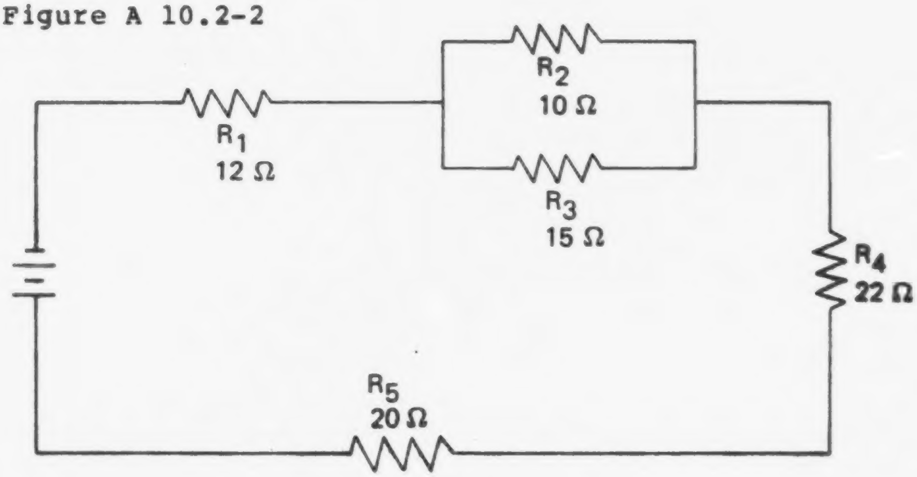
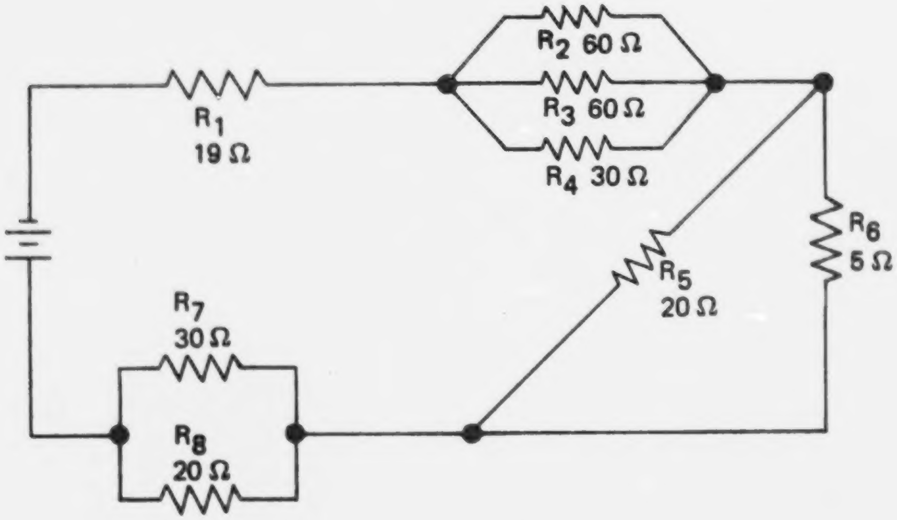

R_1
12 Ω
R_2
10 Ω
R_3
15 Ω
R_4
22 Ω
R_5
20 Ω

Figure A 10.2-2

R_{eq} = ____________________

ACTIVITY SHEET A 10.2 CONT'D.

C. See Figure A 10.2-3

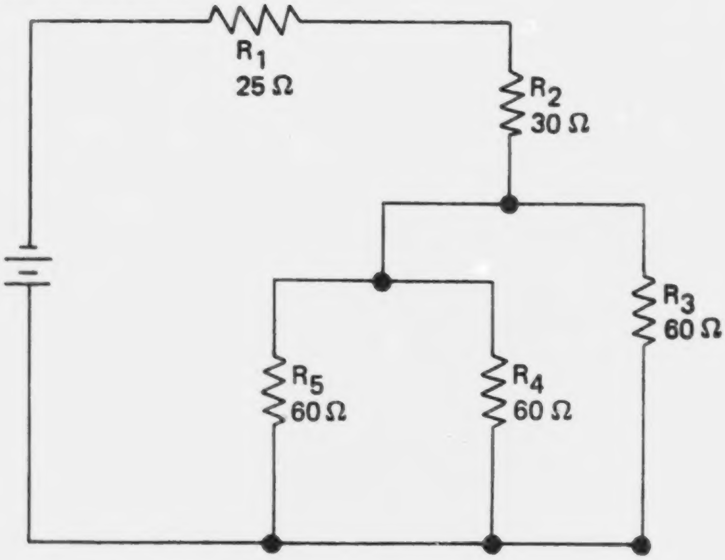


R_2 60 Ω
R_3 60 Ω
R_4 30 Ω
R_1
19 Ω
R_6
5 Ω
R_5
20 Ω
R_7
30 Ω
R_8
20 Ω

Figure A 10.2-3

R_{eq} = ____________________

D. See Figure A 10.2-4



R_1
25 Ω
R_2
30 Ω
R_3
60 Ω
R_5
60 Ω
R_4
60 Ω

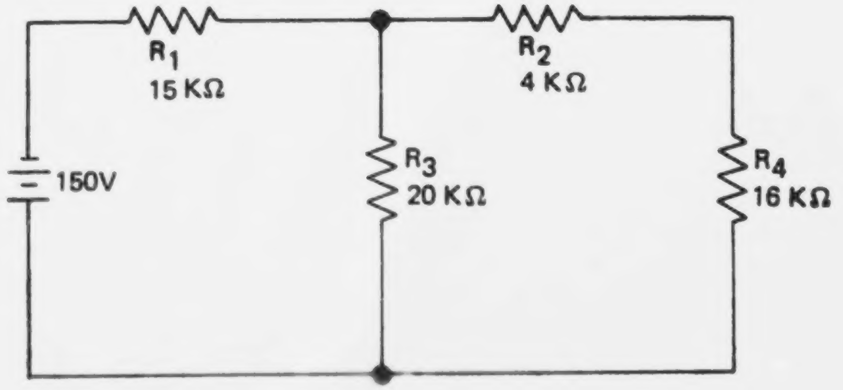
Figure A 10.2-4

R_{eq} = ____________________

ACTIVITY SHEET A 10.2 CONT'D.

Using the circuits in Figures A 10.2-5 and A 10.2-6, find the resistance, voltage, and current values shown below.

Figure A 10.2-5


R_1
15 KΩ
R_2
4 KΩ
150V
R_3
20 KΩ
R_4
16 KΩ

E. 1) R_t = ____________

2) I_t = ____________

3) I_{R_1} = ____________

4) I_{R_3} = ____________

5) $I_{R_{2,4}}$ = ____________

6) Which components are in parallel? ____________

7) Which components are in series? ____________

____

8) E_{R_1} = ____________

9) E_{R_3} = ____________

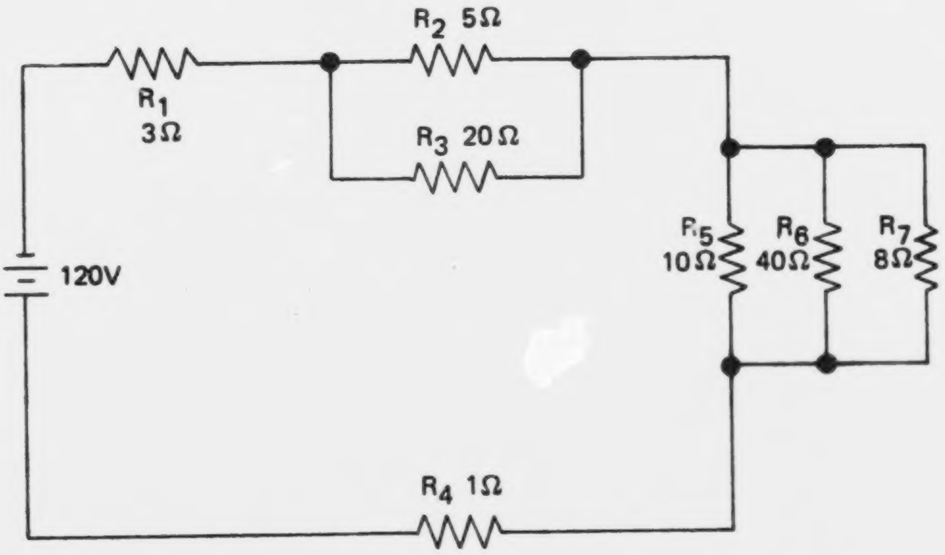
10) $E_{R_{2,4}}$ = ____________

11) E_{R_2} = ____________

12) E_{R_4} = ____________

ACTIVITY SHEET A 10.2 CONT'D.

Figure A 10.2-6



R_2 5Ω
R_1 3Ω
R_3 20Ω
120V
R_5 10Ω
R_6 40Ω
R_7 8Ω
R_4 1Ω

F. 1) R_t = ________________

2) I_t = ________________

3) I_{R_2} = ________________

4) I_{R_3} = ________________

5) I_{R_4} = ________________

6) I_{R_5} = ________________

7) I_{R_6} = ________________

8) I_{R_7} = ________________

9) E_{R_1} = ________________

10) E_{R_2} = ________________

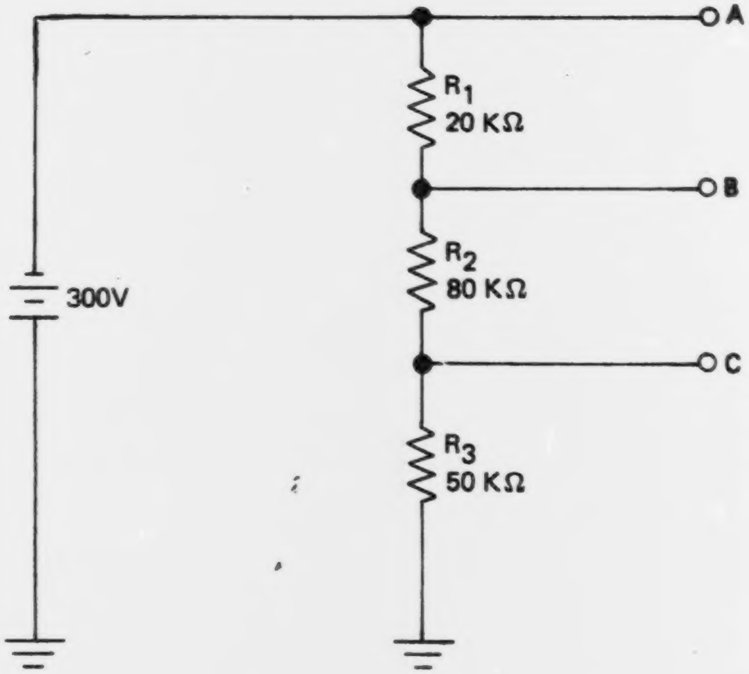
11) E_{R_6} = ________________

12) E_{R_4} = ________________

ACTIVITY SHEET A 10.2 CONT'D.

Calculate the voltages available from the voltage dividers in Figures A 10.2-7 and A 10.2-8

Figure A 10.2-7



G. 1) Voltage at Point A with respect to Gnd = ______________

2) Voltage at Point B with respect to Gnd = ______________

3) Voltage at Point C with respect to Gnd = ______________

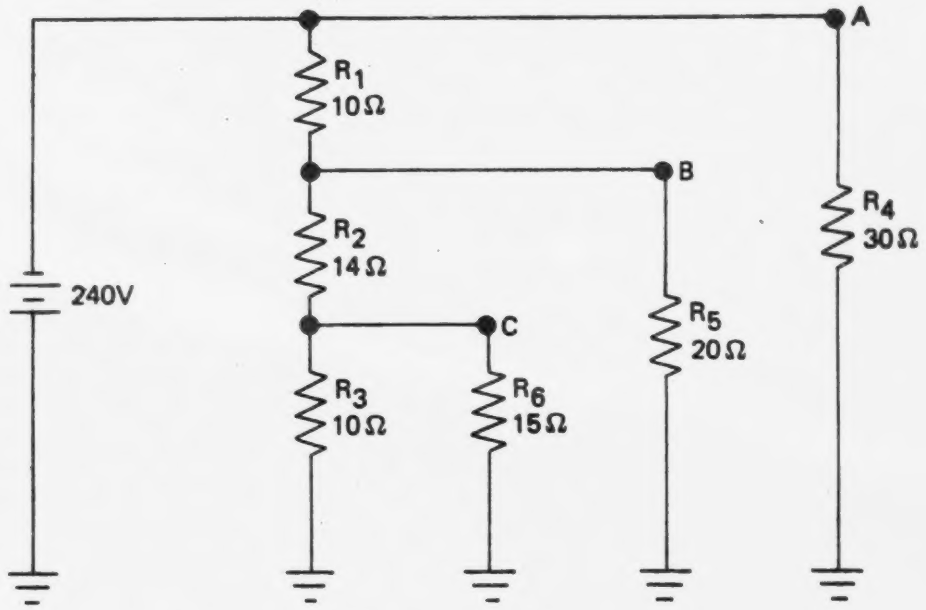
4) Voltage at Point C with respect to Point A = __________

5) Voltage at Point B with respect to Point C = __________

6) Voltage at Point B with respect to Point A = __________

ACTIVITY SHEET A 10.2 CONT'D.

Figure A 10.2-8


A
R1
10Ω
B
R4
30Ω
R2
14Ω
240V
C
R5
20Ω
R3
10Ω
R6
15Ω

H. 1) Voltage at Point A with respect to Gnd = ____________

2) Voltage at Point A with respect to Gnd = ____________

3) Voltage at Point C with respect to Gnd = ____________

ACTIVITY SHEET A 10.2

ANSWER KEY

A. 100 Ω

B. 60 Ω

C. 50 Ω

D. 75 Ω

Figure A 10.2-5

E. 1) 25 KΩ
   2) 6 mA
   3) 6 mA
   4) 3 mA
   5) 3 mA
   6) R_2 and R_4 with R_3
   7) R_2 and R_4; R_1 with R_2, R_3 and R_4
   8) 90 V
   9) 60 V
   10) 60 A
   11) 12 V
   12) 48 V

Figure A 10.2-6

F. 1) 12 Ω
   2) 10 A
   3) 8 A
   4) 2 A
   5) 10 A
   6) 4 A
   7) 1 A
   8) 5 A
   9) 30 V
   10) 40 V
   11) 40 V
   12) 10 V

Figure A 10.2-7

G. 1) 300 V
   2) 260 V
   3) 100 V
   4) -200 V
   5) 160 V
   6) -40 V

Figure A 10.2-8

H. 1) 240 V
   2) 120 V
   3) 36 V

ACTIVITY SHEET

A 10.3

VOLTAGE & CURRENT DIVIDER PROBLEMS

1. Determine the voltage division across R_1 A R_2 of Figure A 10.3-1.

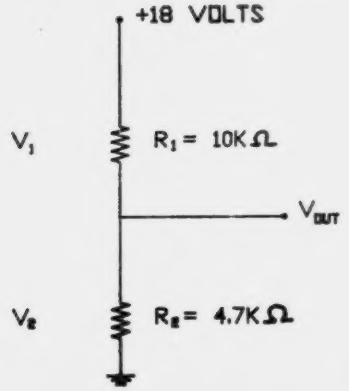

+18 VOLTS
V1
R1 = 10KΩ
VOUT
V2
R2 = 4.7KΩ

Figure A 10.3-1

2. What is the voltage from point A to ground for the circuit of Figure A 10.3-2?

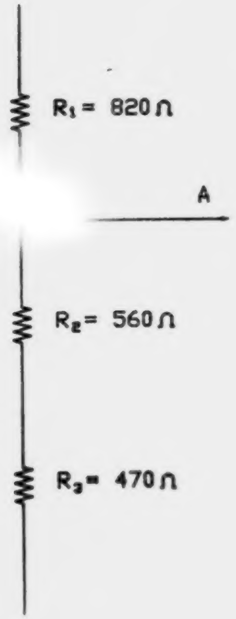

R1 = 820Ω
A
R2 = 560Ω
R3 = 470Ω

Figure A 10.3-2

211

ACTIVITY SHEET A 10.3 CONT'D.

3. How much voltage is dropped across resistor R_3 in Figure A 10.3-3?

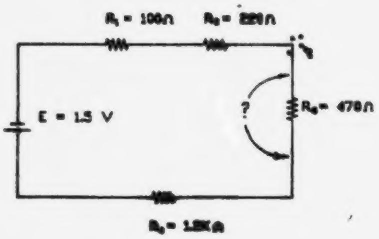

R_1 = 100Ω
R_2 = 220Ω
R_3 = 470Ω
?
E = 1.5 V
R_4 = 1.2KΩ

Figure A 10.3-3

4. Using Figure A 10.3-3, what is the voltage from point A to point B?

5. Refer to Figure A 10.3-4. What is the voltage from point A to B?

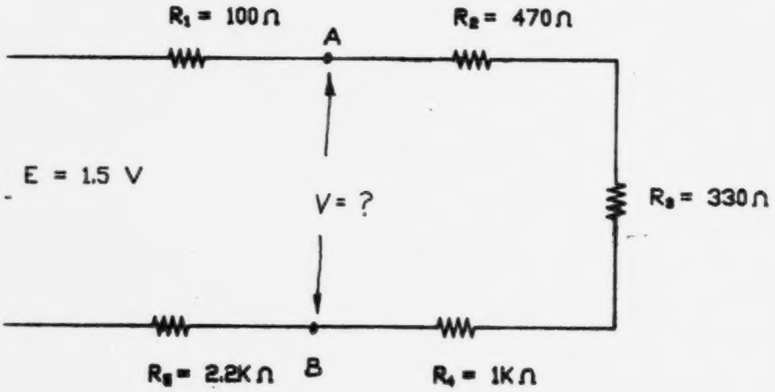

R_1 = 100Ω
A
R_2 = 470Ω
E = 1.5 V
V= ?
R_3 = 330Ω
R_5 = 2.2KΩ
B
R_4 = 1KΩ

Figure A 10.3-4

ACTIVITY SHEET A 10.3 CONT'D.

6. What is the value of I_1 in the circuit represented by Figure A 10.3-5?

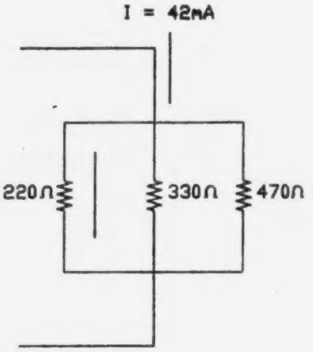

I = 42mA
220Ω
330Ω
470Ω

Figure A 10.3-5

7. How will the current divide in Figure A 10.3-6?

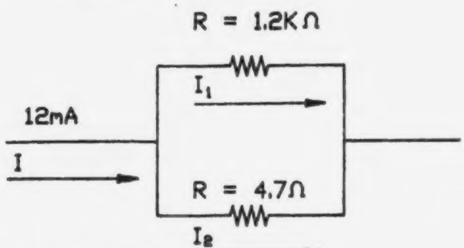

R = 1.2KΩ
I₁
12mA
I
R = 4.7Ω
I₂

Figure A 10.3-6

8. Find the value of I_4 in Figure A 10.3-7.

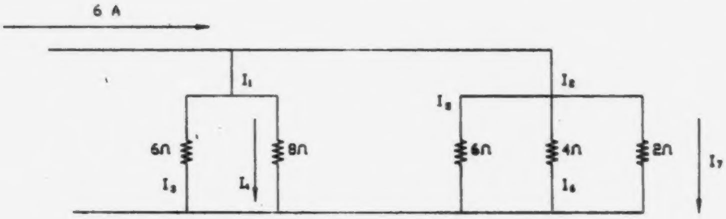

6 A
I₁
I₂
I₅
6Ω
8Ω
6Ω
4Ω
2Ω
I₇
I₃
L₄
I₆

Figure A 10.3-7

9. What is the value of I_7 in Figure A 10.3-7?

ACTIVITY SHEET A 10.3 CONT'D.

10. "The current entering any number of parallel resistors divides into the resistors as the ______________ratio of their ohmic values."

See Figure A 10.3-8

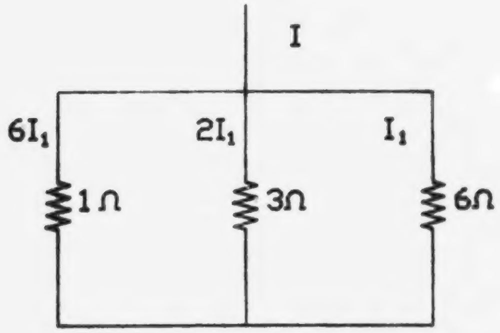


Figure A 10.3-8

ACTIVITY SHEET A 10.3

ANSWER SHEET

1. $$V_x = \frac{R_x\ V}{R_T}$$

V_x = unknown voltage
R_x = value of resistor
V = supplied voltage

$$V_1 = \frac{R_1\ V}{14.7\ K\Omega} = \frac{10K \times 18V}{14.7\ K\Omega} = V_1 = 12.25 \text{ volts}$$

$$V_2 = \frac{R_2\ V}{14.7\ K\Omega} = \frac{4.7K \times 18}{14.7\ K\Omega} = V_2 = 5.755 \text{ volts}$$

Could have also subtracted V_1 from total voltage.

$(V_2 = V_T - V_1)$

2. $$V^1{}_T = \frac{R^1{}_T\ V}{R_T}$$ $R^1{}_T$ = Two or more resistors in series.

$$V^1{}_T = \frac{(560 + 470)\ 36)}{(820 + 560 + 470)}$$ $V^1{}_T$ = Voltage A to I

$V^1{}_T = 20.04$ volts

3. $$V_x = \frac{R_x\ V}{R_T} = \frac{470 \times 1.5}{1990\ \Omega}$$

$V_x = 354$ m Volts

4. $$V^1{}_T = \frac{R^1{}_T\ V}{R_T} = \frac{1.67K\Omega \times 1.5\ V}{1.99K\Omega} = 1.259 \text{ volts}$$

5. $$V^1{}_T = \frac{R^1{}_T\ V}{R_T} = \frac{1.8K\Omega \times 1.5\ V}{4.1K\Omega} = 658.5 \text{ mV}$$

ACTIVITY SHEET A 10.3 CONT'D.

6. $$I_x = \frac{R_T\ I_T}{R_x}$$

I_x = branch current required
R_x = branch resistance
R_T = total resistance I_T = Total I
R_T = 220//330//470 = 103

$$I_x = \frac{103 \quad \times 42 \text{ mA}}{220}$$

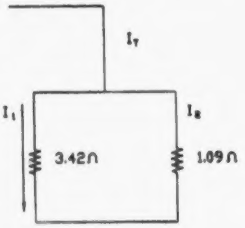
$I_x = 19.67$ mA

7. $$I_1 = \frac{R_2\ I_T}{R_1 + R_2} = \frac{4.7\Omega \times 12 \text{ mA}}{1.2\text{K} + 4.7\text{K}} = 9.56 \text{ mA}$$

$I_1 = 9.56$ mA
$I_2 = I_T - I_1 = 12$ mA $- 9.56 = 2.44$ mA

8. Divide the inverse of Ohmic value.

Redraw and simplify



9. $I_2 = 3.135 \times I_1$
$I_2 = 4.353$ A

$I_2 = I_5 + I_6 + I_7$

I_7 = will take 3 times
as much and twice that
of I_6.

$I_T = 6$A
$I_T = I_x + 3.135\ I_x$
$6\text{A} = 4.135\ I_x$
$I_x = 1.45$
$I_3 = 1.33\ I_x$
$I_4 = .75\ I_x$

$I_1 = I_x$
$I_2 = 3.135\ I_x$
$I_1 = 1.45$ A
$I_2 = 4.353$ A
$I_4 = 1.0875$ A

So, $I_2 = I_5 + 2I_5 + 3I_5$
$I_2 = 6I_5$
$4.353 = 6I_5$ $\quad I_5 = 725.5$ mA

$I_7 = 3(I_5)$
$I_7 = 3(725.5 \text{ mA}) = 2.177$A

10. Inverse

PROGRAM: ELECTRONICS

TASK: VOLTAGE DIVIDERS

TASK #: A 10.4

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE __________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT __________

TERMINAL PERFORMANCE OBJECTIVE:

ANALYZE, CONSTRUCT, AND TROUBLESHOOT RESISTIVE VOLTAGE DIVIDERS (LOADED AND UNLOADED) USING KIRCHOFF'S LAW AND OHM'S LAW.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out 7 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

VOLTAGE DIVIDERS

A 10.4

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the circuit wired according to the schematic?	Y N
* 2.	Does the circuit function properly?	Y N
3.	Was necessary data recorded?	Y N
* 4.	Was the correct equipment used?	Y N
* 5.	Was the equipment used correctly?	Y N
* 6.	Were safety precautions followed?	Y N
7.	Was the equipment returned to proper storage area?	Y N

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

STUDENT'S SCORE ____

VOLTAGE DIVIDERS

EXAM

A 10.5

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Voltage Dividers. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer a minimum of 8 out of 10 items correctly, 80%.

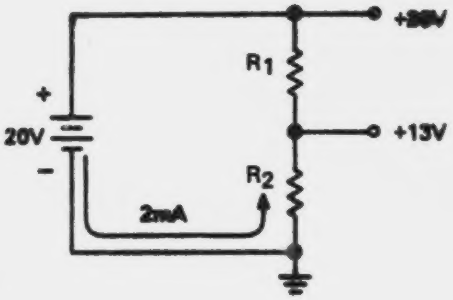
VOLTAGE DIVIDERS

EXAM

A 10.5

Calculate the following values:

1. See Figure A 10.5-1.

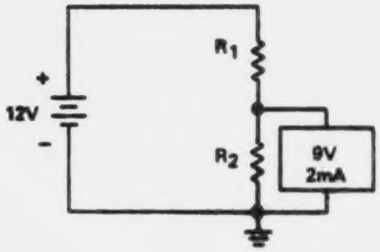

+20V
R1
+
20V
-
+13V
R2
2mA

R_2 = ________________.

Figure A 10.5-1

A. 3.5 KΩ
B. 7.5 KΩ
C. 6.5 KΩ
D. 10 KΩ

2. See Figure A 10.5-2


R1
+
12V
-
R2
9V
2mA

I_{R_1} = ____________.

Figure A 10.5-2

A. 2.2 A
B. 20.2 mA
C. .22 mA
D. 2.2 mA

EXAM A 10.5 CONT'D.

3. As a rule of thumb for voltage dividers: ___% of the load current is selected as bleeder current.

   A. 33%
   B. 25%
   C. 10%
   D. 1%

4. A 100 watt light bulb requires 120 volts; what is its resistance?

   A. 14.4 KΩ
   B. 120 ohms
   C. 1.2 ohms
   D. 144 ohms

5. See Figure A 10.5-3

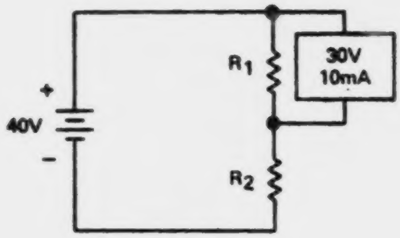


Figure A 10.5-3

I_{R_1} = __________.

   A. .1 A
   B. 10 mA
   C. 1 mA
   D. .01 A

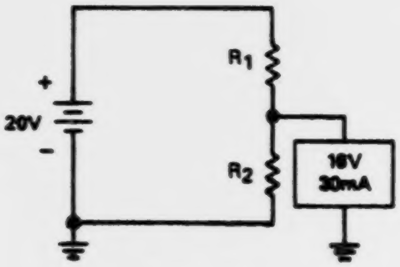
6. Any circuit or device that draws current and/or has resistance, requires voltage, or dissipates power is defined as ______________.

   A. a voltage generator
   B. a load
   C. an alternator
   D. a short circuit

7. A point that is at the same potential as the earth itself is called ______.

A. chassis ground
B. the minus terminal
C. an earth ground
D. the positive terminal

8. See Figure A 10.5-4



I_{R_2} = __________.

Figure A 10.5-4

A. 33 mA
B. 3 mA
C. 300 mA
D. 3 mA

9. The next step in designing a voltage divider after examining the power supply and load requirements is __________.

A. to draw a schematic
B. to select the bleeder current
C. to turn on the switch
D. to calculate the current

10. R_2 of Schematic A (Figure A 10.5-5) is called ____________.

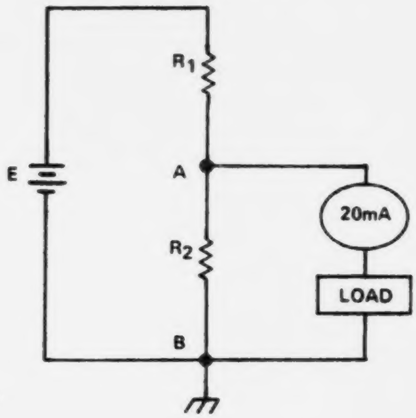

R1
E
A
20mA
R2
LOAD
B

Figure A 10.5-5

A. the load
B. a needless bypass
C. a bleeder resistor
D. a power saver

EXAM A 10.5

ANSWER KEY

1. C
2. D
3. C
4. D
5. C
6. B
7. C
8. B
9. B
10. C

ELECTRONICS

ANALYZING DC CIRCUITS

A 11: NETWORK THEOREM ANALYSIS

TASK: Solve basic linear electrical circuits using network theorem analysis.

PURPOSE: Many complex series-parallel circuits are solved by using network theorems. Ohm's Law only offers an answer to relatively simple circuit variables. Network theorems can be an important tool in simplifying complex circuits. In this learning guide you will be introduced to many network theorems and their applications to electronic circuits.

OBJECTIVE: Given access to all necessary tools and equipment, you will solve basic linear electrical circuits using network theorem analysis.

ESTIMATED CLASS TIME: 3 HOURS

NETWORK THEOREM ANALYSIS

LEARNING STEPS

A 11

READ: Information Sheet A 11.1 on "Network Theorems."

READ: Information on network theorems from the following resource list.

VIEW: Audio/Visual material on network theorems. Contact your instructor.

COMPLETE: Activity Sheet A 11.2 on "Network Theorems."

COMPLETE: Lab Performance on network theorems. Contact your instructor for this lab.

COMPLETE: Performance Checklist A 11.3. Contact your instructor.

REVIEW: All material covered in this learning guide and information presented by your instructor.

COMPLETE: Written Exam A 11.4. Contact your instructor.

NETWORK THEOREM ANALYSIS

RESOURCES

A 11

1. BASIC ELECTRICITY AND CIRCUIT CONCEPTS: VOL. 1, DC CIRCUITS, Oliva and Dale (Radio Shack: Texas Instrument Learning Center, 1979), 4th Edition. Chapter 1.

2. DC ELECTRONICS (Heathkit Educational Systems, 1984). Units I & II.

3. BASIC ELECTRONICS, Grob (McGraw-Hill, 1984). Chapter 1.

4. INTRODUCTION TO ELECTRICITY AND ELECTRONICS, Bell & Howell Schools (DeVry Institute of Technology, 1984). Chapter 1001.

5. INTRODUCTION TO INDUSTRIAL ELECTRICITY-ELECTRONICS (Oklahoma Trade and Industrial Education).

6. ELECTRONICS: PRINCIPLES AND APPLICATIONS, Badrkhan and Larky (South Western Pub.). Chapter 1.

7. ELECTRICITY ONE-SEVEN, Mileaf (Hayden). Chapter 1.

8. ELECTRONIC COMMUNICATION, Schrader (McGraw-Hill Pub. Co.). 5th Ed. Chapter 1.

INFORMATION SHEET

A 11.1

NETWORK THEOREMS

Series-parallel circuits can become highly complex. A circuit that includes multiple electrical or electronic components is known as an electrical/electronic network.

The most common technique for solving these circuits is to use network theorems. A theorem is a rule or set of rules that can be proven mathematically. In the course of mathematical proof, it is necessary to work through a series of related, sequential equations. Network theorems are techniques for finding a partial or complete solution to a circuit; these analysis tools save time and labor when developing new circuits. It is time consuming to solve a circuit for each resistance or characteristic change necessary to provide the outcomes you expect. With a partial solution the component in question can be easily substituted or changed, and then a complete solution can be accomplished.

There are a lot of theorems that can be applied to network circuits. But, in practice, one or two theorems are all that's needed in most network analysis. Some of the most familiar theorems are:

A) Kirchhoff's Current Law
B) Kirchhoff's Voltage Law
C) Superposition Theorem
D) Thevenin's Theorem
E) Norton's Theorem
F) Millman's Theorem

Additional tools which are used in conjunction with the network theorems are Mesh and Node equations. Mesh equations are used to find loop currents in a complex circuit and Node equations are used to find the node voltage. Node analysis is similar to Millman's Theorem.

Kirchhoff's Current Law

Kirchhoff's current law states: The amount of current entering a point or node is equal to the current leaving that point or node. Also, the algebraic sum of the currents entering and leaving the point or node is equal to zero. The equation for Kirchhoff's current law is:

$$I_{in} - (I_{R1} + I_{R2}) = 0$$

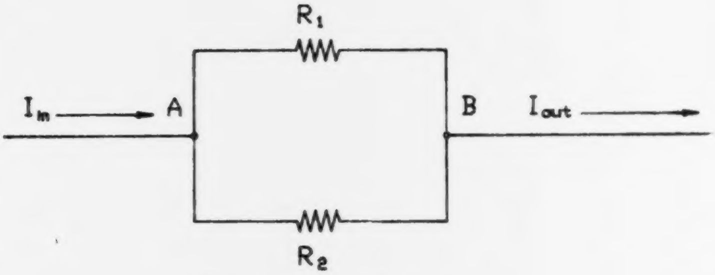


Figure A 11.1-1

Using figure A 11.1-1 to explain Kirchhoff's current law: If I_{in} = 2A and $R_1 = R_2$, then $I_{R1} = I_{R2}$ = 1A. Substituting into equation above, 2A -(1A + 1A) = 0. This indicates that I_{in} = I_{out} therefore, the current leaving the source must be equal to the current returning to the source.

Kirchhoff's Voltage Law

Kirchhoff's law for voltage can be stated in two separate ways:

A) The algebraic sum of voltage drops and voltage rises around any closed series loop (or path) is equal to zero.

$$E_{total} - E_1 - E_2 - \dots - E_n = 0$$

B) The sum of voltage drops around any closed series path (or loop) is equal to the sum of voltage rises.

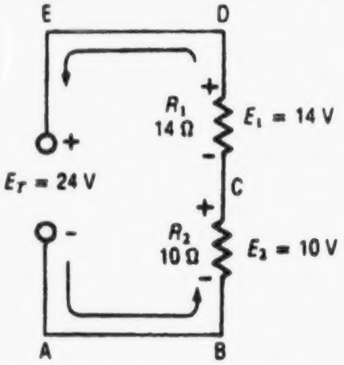


Figure A 11.1-2

24v = 10v + 14v

Superposition Theorem

The superposition theorem is used to simplify circuits which contain two or more current or voltage sources. The theorem solves for the current or voltage at a point within a circuit.

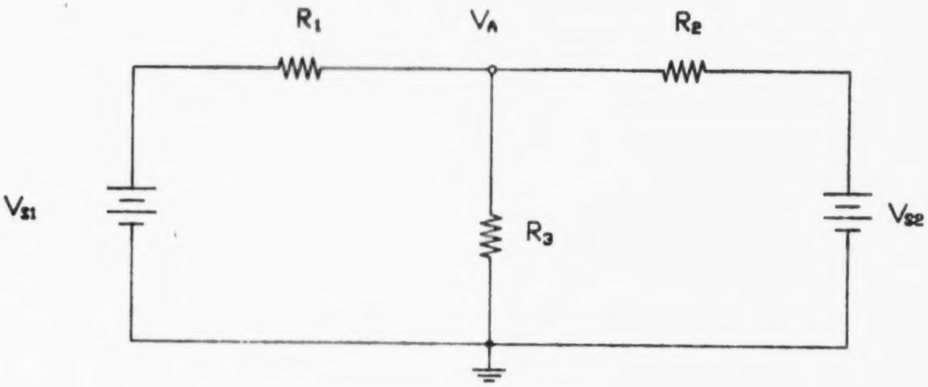


Figure A 11.1-3

To simplify or solve this circuit (Figure A 11.1-3) using the superposition theorem, follow these standard rules to find the node voltage V_A.

INFORMATION SHEET A 11.1 CONT'D.

1. Voltage sources must be shorted.
2. Current sources must be open.
3. Two solutions are required..
   NOTE: The total number of solutions will equal the number of sources in the circuit.
4. To solve for V_A' in reference to V_{S1}, short V_{S2}.
5. To solve for V_A'' in reference to V_{S2}, short V_{S1}.
6. V_A will be equal to the algebraic sum of each source solution.

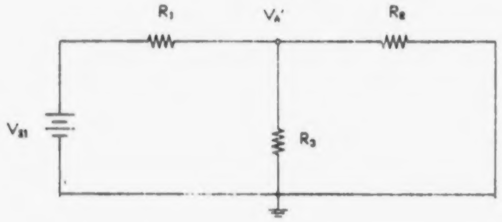


Figure A 11.1-4

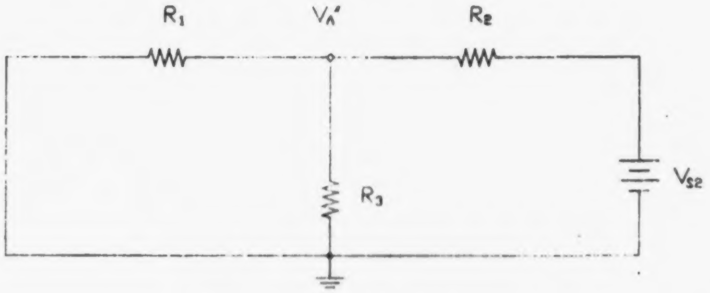


Figure A 11.1-5

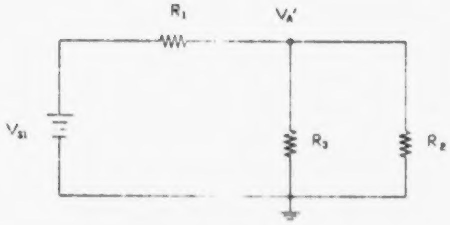


Figure A 11.1-6

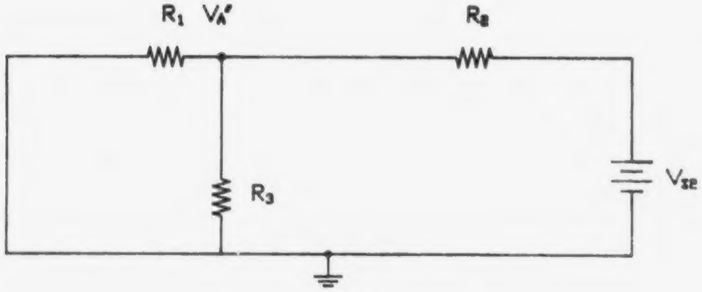


Figure A 11.1-7

Figure A 11.1-4 depicts the first step for finding the node voltage V_A. Source V_{S2} is shorted, which results in R_3 being in parallel to R_2 (Figure A 11.1-6). This circuit can now be solved as a simple series-parallel circuit to find the voltage drop across R_1 and R_2 parallel to R_3. The voltage drop across R_2 parallel to R_3 is not the final node voltage. The circuit must now be solved in reference to source V_{S2} (Figure A 11.1-5). The simple series-parallel circuit is shown in Figure A 11.1-7); again solve for the voltage drops across the resistances R_2 and R_1 parallel to R_3.

The final node voltage V_A will be equal to the algebraic sum of the voltage drops across the parallel resistances.

$V_A = V_{R2}$ parallel to R3 + V_{R1} parallel to R2

An example using the Superposition Theorem follows:

Using Figure A 11.1-3

$V_{S1} = 20V$ $\qquad$ $R_1 = 2K\Omega$

$V_{S2} = 12V$ $\qquad$ $R_2 = 3K\Omega$

$R_3 = 10K\Omega$

Shorting out V_{S2}, using Figure A 11.1-6, with R3 parallel to R2 and using Ohm's law, the voltage is equal to:

$$R_2 \text{ parallel to } R_3 = \frac{R_2 \times R_3}{R_2 + R_3}$$

$$= \frac{30\ M\Omega}{13\ K\Omega}$$

$$= 2.30\ 6K\Omega$$

$$V_A' = \frac{R_2 \text{ parallel to } R_3}{R_1 + (R_2 \text{ parallel to } R_3)} \times V_{S1}$$

$$V_A' = \frac{2.3076K\Omega}{4.3076K\Omega} \times 20V$$

$$V_A' = +10.714V$$

Shorting out V_{S1} using Figure A 11.1-7 where R1 parallel R3, the voltage is:

$$R_1 \text{ parallel to } R_3 = \frac{R_1 \times R_3}{R_1 + R_3}$$

$$= \frac{20M\Omega}{12K\Omega}$$

$$= 1.6\overline{6}K\Omega$$

$$V_A'' = \frac{R_1 \text{ parallel to } R_3}{R_2 + (R_1 \text{ parallel to } R_3)} \times V_{S2}$$

$$V_A'' = \frac{1.6\overline{6}K\Omega}{4.6\overline{6}K\Omega} \times 12V$$

$$V_A'' = +\ 4.2857V$$

Therefore, $V_A = V_A' + V_A''$

$$V_A = 15V$$

Thevenin's Theorem

Thevenin's Theorem is used to simplify the relationship between voltage sources and drops in a network, making it easier to determine applied voltage. Its basic conception is that any circuit can be reduced, or simplified, to an equivalent circuit consisting of a single supply voltage, a related single supply resistance and a single load resistance. Therefore, a very complicated circuit can be reduced to a Thevenin equivalent.

INFORMATION SHEET A 11.1 CONT'D.

Thevenin's Theorem states that the current in any load resistance connected to two terminals of a network consisting of any number of resistors and/or voltage sources is the same as though the load resistance were connected to a single source whose open circuit voltage of the two terminals and whose resistance is the equivalent resistance looking into the terminals.

Mathematically speaking: $I_t = \dfrac{E_{Thevenin}}{R_{Thevenin}}$

In applying Thevenin's Theorem to determine either voltage or current, begin by simplifying the circuit. Consolidate all resistances to equal one resistance = R_{TH}. All voltages are represented as a single voltage = E_{TH}. Once these values have been found, Thevenin's Theorem can make almost any complex circuit a simple one.

An example of a Thevenin circuit is as follows. the Thevenin voltage is known as the terminal voltage and the Thevenin resistance is found by shorting out the voltage source.

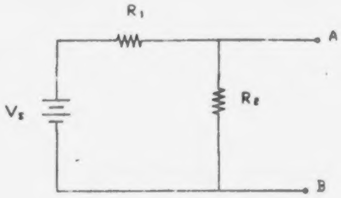


Figure A 11.1-8

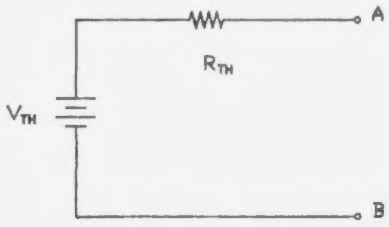
The Thevenin voltage V_{TH} is equal to:

$$V_{TH} = V_S \frac{R_2}{R_1 + R_2},$$

and the Thevenin resistance, with V_S shorted, is equal to:

$R_{TH} = R_1$ parallel to R_2,

the Thevenin equivalent circuit is:



Using the same circuit, Figure A 11.1-8, that was used in the Thevenin example, a Norton circuit can be derived. A Norton circuit uses a current rather than voltage source.

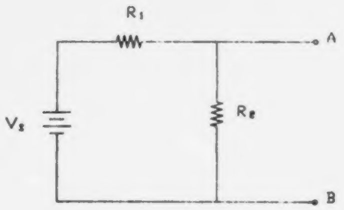


Figure A 11.1-8

the Norton equivalent is Figure A 11.1-9

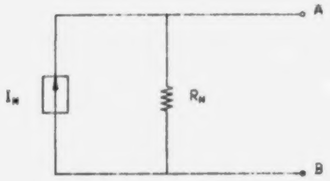


Figure A 11.1-9

where

$$I_N = \frac{V_s}{R_1} \qquad R_N = R_1 || R_2,$$

Norton's Theorem

Norton's Theorem is still another approach to solving complex network circuits. Whereas Thevenin's Theorem simplified circuits in terms of resistance and voltage, Norton's Theorem says that any complex circuit can be simplified to an equivalent circuit consisting of a single supply current, a related, single parallel internal resistance, and a single load resistance.

Norton's Theorem states that the current in any load resistance, R_L, connected to two terminals of a network consisting of any number of resistors and/or current sources is the same as though R_L were connected to a constant current source whose current is equal to the current that flows through the two terminals when they are short-circuited. This assumes that the constant current source is across a resistance equal to the resistance of the network-looking back from the two terminals.

NOTE:

Norton's and Thevenin's theorems assume ideal current and voltage sources. In practice, voltage and current sources have internal resistances that can affect circuit analysis.

Using the same circuit, Figure A 11.1-8, that was used in the Thevenin example, a Norton circuit can be derived. A Norton circuit uses a current rather than voltage source.

Millman's Theorem

Millman's theorem is appropriate for use with networks that have many sources, making applications of either Norton or Thevenin techniques tedious.

Millman's theorem states that each voltage source branch within a circuit may be changed to its Norton-current source equivalent; that these current sources may be analyzed along with whatever parallel current sources are originally part of the circuit and with whatever resistances result from the Norton equivalent along with whatever resistances are originally part of the circuit. An example is shown in Figure A 11.1-10.

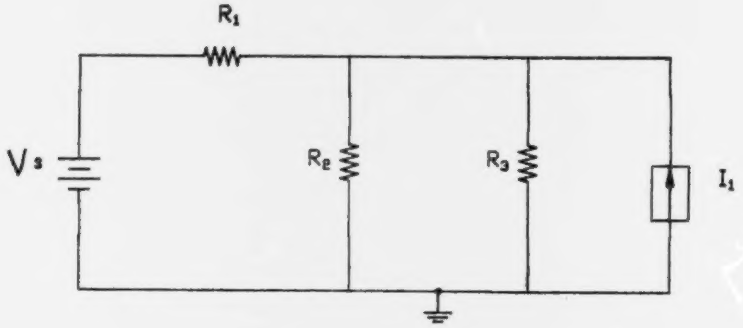
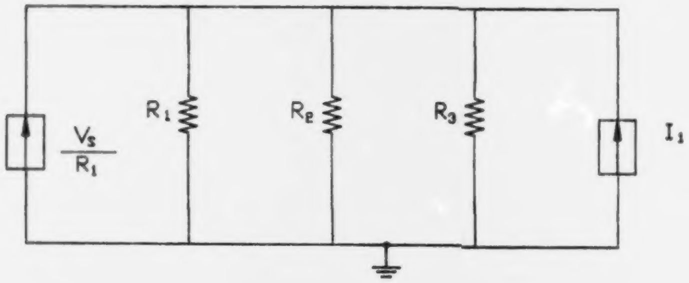


Figure A 11.1-10

The equivalent circuit is as follows and Kirchhoff's Current Law can be used to solve this circuit.



INFORMATION SHEET A 11.1 CONT'D.

The concept of Millman's theorem is to change each voltage-source branch within a circuit to it's Norton-current source equivalent. These are then analyzed along with whatever parallel current sources are originally part of the circuit. The original resistances plus those developed from the Norton equivalent are also used.

No matter what complex network analysis technique is used, each has its own advantages and applications. The information in this learning guide has only introduced you to some network theorems that can be used to solve complex series-parallel circuits. You will need more circuit analysis information that is provided in other reference material. You are to continue with this learning guide.

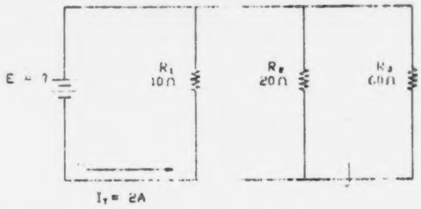
ACTIVITY SHEET

A 11.2

NETWORK THEOREM ANALYSIS

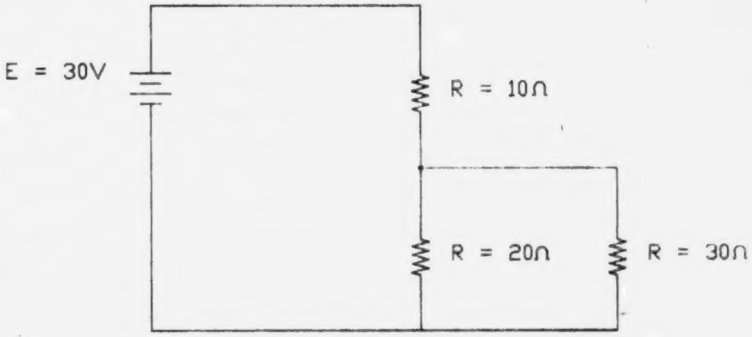
DIRECTIONS: Complete each question. DO NOT CONTINUE with any portion of this guide until the Activity Sheet has been completed. If you need any help, see your instructor.

1. Find R_T, E, I_{R_1}, I_{R_2}, and I_{R_3}.

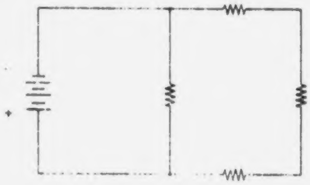

E = ?
R₁ 10Ω
R₂ 20Ω
R₃ 60Ω
I_T = 2A

2. Algebraically, state Kirchhoff's Current Law:

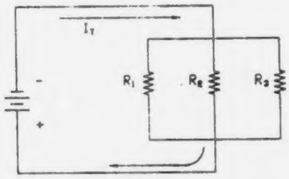
3. Find R_{TH} and E_{TH}:


E = 30V
R = 10Ω
R = 20Ω
R = 30Ω

4. Using electron current flow, assign correct polarities to the following circuit and show direction of current flow.

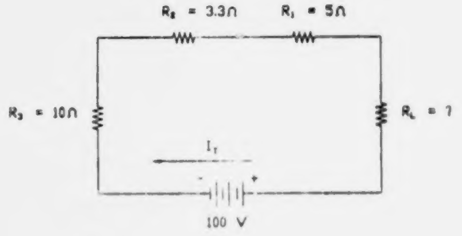


5. Write an equation for I_T.

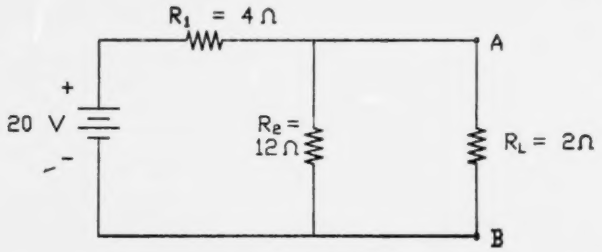


ACTIVITY SHEET A 11.2 CONT'D.

6. A current of 3A flows in this circuit, find value of R_L.


R_2 = 3.3Ω
R_1 = 5Ω
R_3 = 10Ω
R_L = ?
I_T
-
+
100 V

7. Show the Thevenin equivalent and calculate V_L.


R_1 = 4Ω
A
+
20 V
-
R_2 = 12Ω
R_L = 2Ω
B

8. The equivalent Thevenin resistance R_{TH} is the resistance seen between the same two terminals of the original circuit when the internal voltage sources are assumed to be ____________________________.

9. If a given circuit has 2A of current and 10Ω resistance, what is the voltage?

10. Kirchhoff's Voltage Law states:

ACTIVITY SHEET A 11.2

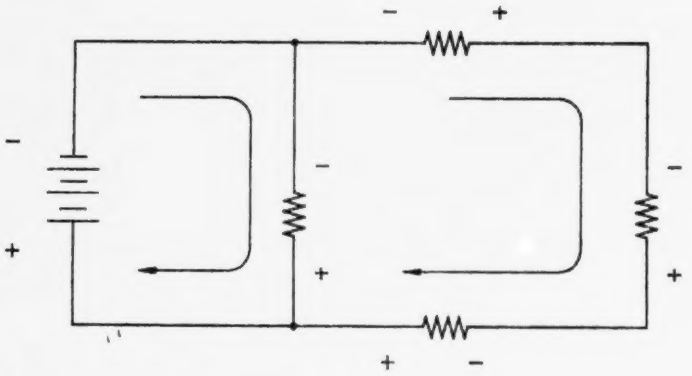
ANSWER SHEET

1. $R_T = 6\,\Omega$, $E = 12V$, $I_{R_1} = 1.2A$, $I_{R_2} = .6A$, $I_{R_3} = .2A$

2. $I_T = I_1 + I_2 + I_3$

3. $R_{TH} = 6.67\,\Omega$, $E_{TH} = 20V$

4.



5. $I_T = I_{R_1} + I_{R_2} + I_{R_3}$

6. $R_L = 15\,\Omega$

7. $V_{TH} = 15_v$ $R_{TH} = 3\,\Omega$ $V_L = 6$

8. Zero or short-circuited

9. 20V

10. The sum of voltage drops around any closed series path (or loop) is equal to the sum of voltage rises.

PROGRAM: ELECTRONICS

TASK: NETWORK THEOREM ANALYSIS

TASK #: A 11.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________

EVALUATION SITE __________

EVALUATOR'S NAME ____________________

PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT __________

TERMINAL PERFORMANCE OBJECTIVE:

SOLVE BASIC LINEAR ELECTRICAL CIRCUITS USING NETWORK THEOREM ANALYSIS.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out 7 points or 75% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 7 points or 75%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

NETWORK THEOREM ANALYSIS

A 11.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the circuit wired according to the schematic?	Y N
* 2.	Does the circuit function properly?	Y N
3.	Was necessary data recorded?	Y N
* 4.	Was the correct equipment used?	Y N
5.	Was the equipment used correctly?	Y N
* 6.	Were safety precautions followed?	Y N
7.	Was the equipment returned to proper storage area?	Y N

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

STUDENT'S SCORE ____

NETWORK THEOREM ANALYSIS

EXAM

A 11.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Network Theorem Analysis. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer a minimum of 8 out of 10 items correctly, 80%.

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NETWORK THEOREM ANALYSIS

EXAM

A 11.4

1. Millman's theorems are appropriate for use with networks that have many sources. In such cases, applying either the Thevenin or Norton techniques can become tedious.

   A. True
   B. False

2. The ________________ theorem holds that the effect of two or more sources of current or voltage for any part of a circuit is equal to the algebraic sum of the effect from each source, acting separately.

   A. Thevenin
   B. Norton
   C. Millman
   D. Superposition

3. __________________ theorem is useful for parallel branches with different voltage sources.

   A. Millman's
   B. Superposition
   C. Norton's
   D. Thevenin's

4. A 200-ohm resistor and a 300-ohm resistor are in parallel. In series with them is a 180-ohm resistor. The whole combination is across a 50-ohm generator. What current flows through the generator?

   A. .167A
   B. .3A
   C. .0049A
   D. 1.7A

5. The formula $V_t = IR_1 + IR_2$ is a statement of Kirchhoff's Voltage Law.

   A. True
   B. False

6. Kirchhoff's current law states that the sum of the currents leaving a junction in a circuit is equal to the sum of the currents entering the junction.

   A. True
   B. False

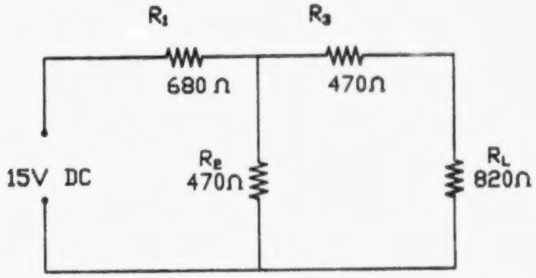
7. In a given circuit I_N = 25mA, R_N = 5 , and R_L = 15 . Solve for the load current.

   A. 10.00 mA
   B. 6.12 mA
   C. 1.47 mA
   D. 16.9 mA

8. One advantage to using a Norton Theorem to solve complex circuits is that many complex circuits cannot be solved with ordinary methods of solution.

   A. True
   B. False

9. The I_L in the circuit below would be about _____ mA.



   A. 3.9
   B. 72
   C. 460
   D. 1

10. Referring to the circuit in problem #9, the I_N would equal:

   A. 14 mA
   B. 8.2 mA
   C. 27.3 mA
   D. 51.2 mA

EXAM A 11.4

ANSWER KEY

1. A
2. D
3. A
4. A
5. B
6. A
7. B
8. A
9. A
10. B

ELECTRONICS

ANALYZING DC CIRCUITS

A 12: MAGNETIC PROPERTIES

TASK: Define magnetic properties of circuits and devices.

PURPOSE: Any wire or conductor carrying a current of electrons is surrounded by an unseen area of force called a magnetic field. For this reason, any study of electricity or electronics must consider magnetism. This learning guide will introduce you to magnetic properties of circuits and devices.

OBJECTIVE: Given access to all necessary tools and equipment, you will define magnetic properties of circuits and devices.

ESTIMATED CLASS TIME: 3 HOURS

MAGNETIC PROPERTIES

LEARNING STEPS

A 12

READ: Information Sheet A 12.1 on "Magnetic Properties."

READ: Information on magnetic properties from the following resource list.

VIEW: Audio/Visual material on magnetic poperties. Contact your instructor.

COMPLETE: Activity Sheet A 12.2 on magnetic poperties.

COMPLETE: Lab Performance on magnetic poperties. Contact your instructor for this lab.

COMPLETE: Performance Checklist A 12.3. Contact your instructor.

REVIEW: All material covered in this learning guide and information presented by your instructor.

COMPLETE: Written Exam A 12.4. Contact your instructor.

MAGNETIC PROPERTIES

RESOURCES

A 12

1. BASIC ELECTRICITY AND CIRCUIT CONCEPTS: VOL. 1, DC CIRCUITS, Oliva and Dale (Radio Shack: Texas Instrument Learning Center, 1979), 4th Edition. Chapter 1.
2. DC ELECTRONICS (Heathkit Educational Systems, 1984). Units I & II.
3. BASIC ELECTRONICS, Grob (McGraw-Hill, 1984). Chapter 1.
4. INTRODUCTION TO ELECTRICITY AND ELECTRONICS, Bell & Howell Schools (DeVry Institute of Technology, 1984). Chapter 1001.
5. INTRODUCTION TO INDUSTRIAL ELECTRICITY-ELECTRONICS (Oklahoma Trade and Industrial Education).
6. ELECTRONICS: PRINCIPLES AND APPLICATIONS, Badrkhan and Larky (South Western Pub.) Chapter 1.
7. ELECTRICITY ONE-SEVEN, Mileaf (Hayden). Chapter 1.
8. ELECTRONIC COMMUNICATION, Schrader (McGraw-Hill Pub. Co.). 5th Ed. Chapter 1.

INFORMATION SHEET

A 12.1

MAGNETIC PROPERTIES

Given is a list of terms and definitions that relate to magnetism. Study each carefully.

I. Terms and Definitions

A. Electromagnet: Magnet created by flow of electricity through coils of wire.

B. North pole: End of magnet which would point toward the earth's South Pole; end from which magnetic lines of force are considered to be exiting.

C. South pole: end of magnet which would point toward the earth's North Pole; end into which magnetic lines of force are considered to be entering.

D. Molecular structure: Form of the natural pattern, ties, and bonds that holds matter together.

E. Polar: Having two distinct ends, each with a different electrical or magnetic property.

F. Alloy: Metal material made by mixing two or more metals.

G. Toroid: Shaped like a ring or doughnut.

H. Magnetism: Invisible force that results from electrons in motion.

I. Natural magnet: Material found in nature which has the quality to attract other materials.

J. Synthetic magnet: Magnets that are produced by magnetizing a piece of iron or steel.

K. Temporary magnet: Magnet produced by passing a current through a coil surrounding a piece of iron or steel; continues only while current is flowing.

L. Retentivity: Ability of material to retain magnetism

M. Residual magnetism: Magnetism remaining in material after charging force has been removed.

N. Reluctance: Resistance of a magnetic path to the flow of magnetic lines of force.

O. Magnetic filed: Area where magnetic force can be detected around a magnet; also called magnetic flux.

There are many electrical devices that utilize magnetism. Here are some of them:

II. Electrical devices utilizing magnetism

A. Electric motor

B. Electric generator or alternator.

C. Relay

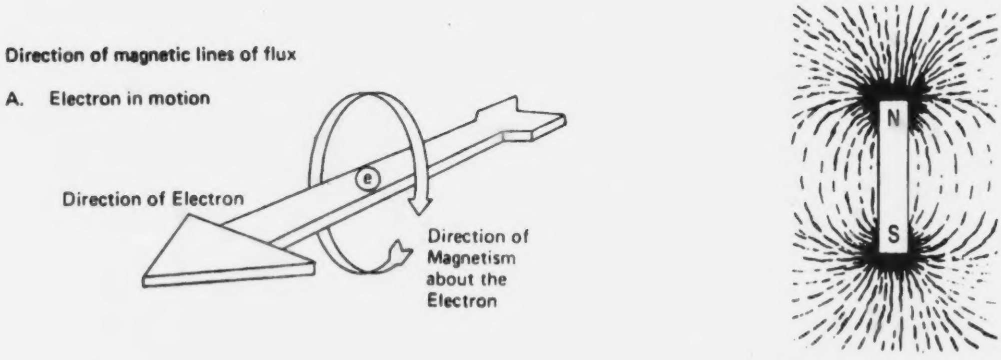
D. Solenoid

E. Electrical meters

F. Speakers

Electrons in motion develop magnetic lines of force called flux lines.

INFORMATION SHEET A 12.1 CONT'D.


Direction of magnetic lines of flux
A. Electron in motion
e
Direction of Electron
Direction of Magnetism about the Electron
N
S

Magnetic field lines

Figure A 12.1-1

The electrons orbiting around the nucleus of an atom or a molecule produce an electromagnetic field around their path in motion.

Electron in orbit around the nucleus of the atom

Direction of Magnetism

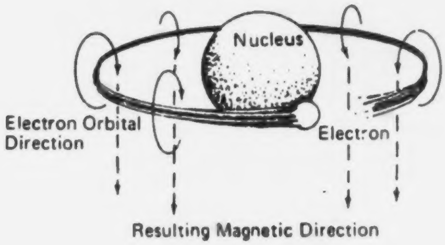

Nucleus
Electron Orbital Direction
Electron
Resulting Magnetic Direction

Figure A 12.1-2

When several turns of wire are formed into a coil, the lines of force from each turn adds to the fields of the other turns and a more concentrated magnetic field is produced in the core of the coil. The more current and the more turns, the stronger the magnetic field, and an electromagnet is produced. Another rule, called the left hand rule for a coil says:

> If a coil is grasped by the left hand with the fingers pointing in the direction of current flow, the thumb indicates the north end of the coil and also the direction of

lines of force in the core. Conversely, if the direction of the lines of force around the core is known, the same left-hand rule for a coil can be applied to determine the current direction in the coil.

LEFT-HAND RULE FOR ELECTROMAGNETS

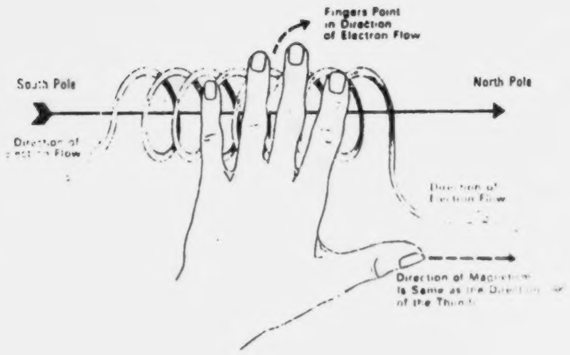

Fingers Point in Direction of Electron Flow
South Pole
North Pole
Direction of Electron Flow
Direction of Electron Flow
Direction of Magnetism Is Same as the Direction of the Thumb

Figure A 12.1-3

Left-hand rule for electromagnets: If a coil of wire is held in the LEFT hand, the fingers curled around the coils point in the direction of electron flow and the extended thumb points in the direction of magnetism, which is called the north pole.

An electron at rest has an electrostatic field of force surrounding it. But, when energy is imparted to an electron to make it move, a new type of field develops around it, at right angles to its electrostatic field. The left-hand rule is useful in analyzing current flow in a conductor.

INFORMATION SHEET A 12.1 CONT'D.

Electron flow in a coil or wire or "electromagnet"

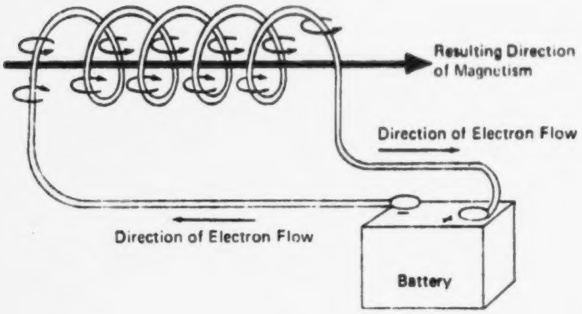

Resulting Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
Battery

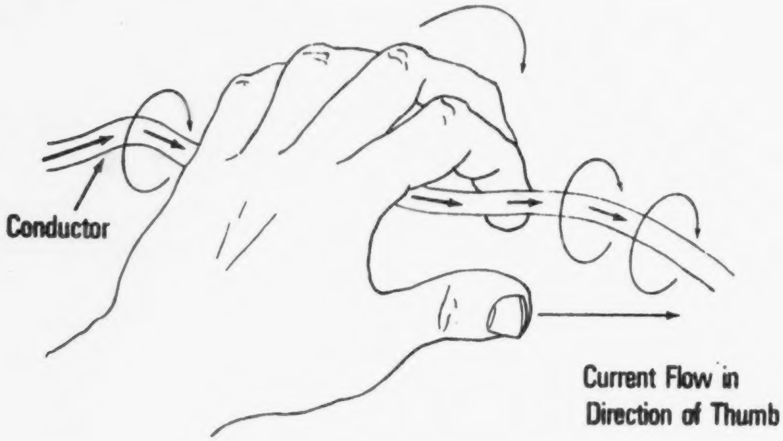
Figure A 12.1-4

(NOTE: To distinguish between the two ends of magnets, the end represented by the arrowhead above is called the north pole and the other end is called the south pole.)

LEFT-HAND RULE FOR MAGNETIC LINES OF FLUX

FINGERS AROUND CONDUCTOR INDICATE

DIRECTION OF MAGNETIC FIELD


Conductor
Current Flow in Direction of Thumb

. Figure A 12.1-5

Whereas electrostatic lines of force are considered as radiating outward from an electron, the electromagnetic field of force develops as a ring around a moving electron, at right angles to the current path.

Electrons in a conductor

(NOTE: Electricity is electrons flowing in a conductor.)

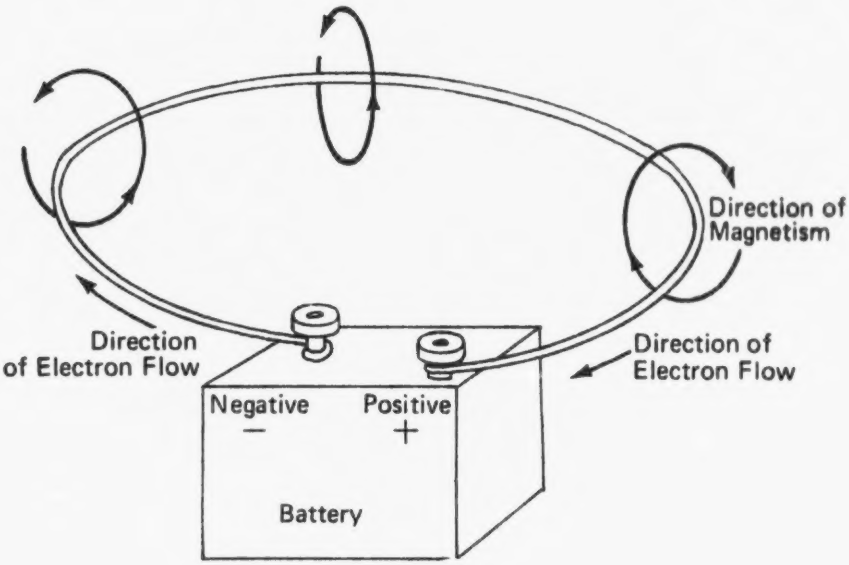

Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
Negative
−
Positive
+
Battery

Figure A 12.1-6

Not all material is magnetic in nature. Here are some examples of magnetic and non-magnetic materials.

Magnetic and non-magnetic metals

A. Magnetic

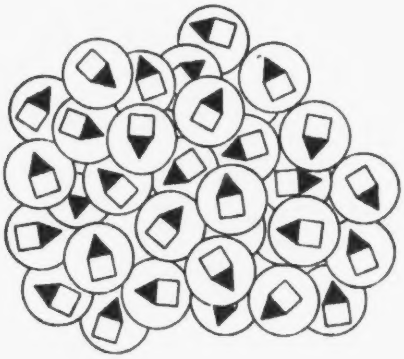
1. Iron
2. Tin
3. Carbon steel
4. Molten aluminum

B. Non-magnetic

1. Copper
2. Brass
3. Aluminum
4. Stainless steel

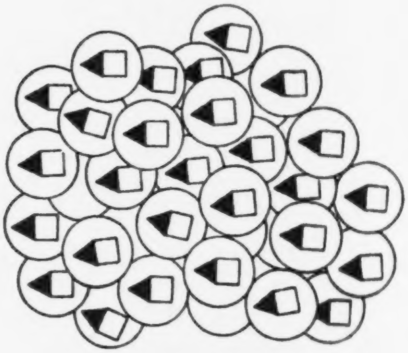
Magnetic material will have groups of atoms that act as tiny magnets and can move to align themselves in one general direction. The net result is magnetism.

MAGNETIC MATERIAL



Groups of Atoms in an Unmagnetized Material
Are Randomly Directed

Figure A 12.1-7

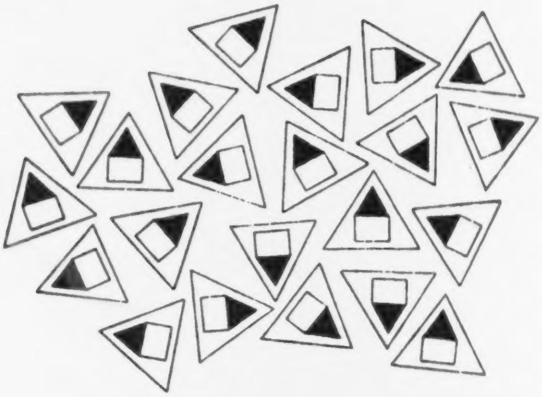


Groups of Atoms in a Magnetized Material
Are Generally Aligned

Figure A 12.1-8

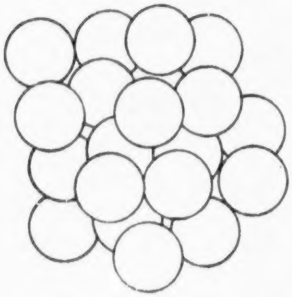
Nonmagnetic materials are groups of atoms that act as tiny magnets but are restricted by their molecular structures from moving into alignment. The net result here is no magnetism.

NONMAGNETIC MATERIAL



Tiny Magnetic Groups of Atoms With Restricted
Polarity Cannot Be Magnetized

Figure A 12.1-9



Nonmagnetic materials

Figure A 12.1-10

There are many methods of increasing the strength of an electromagnet:

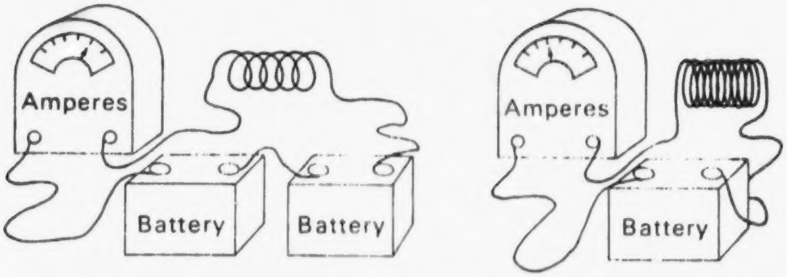
A. Increase flow of electricity through coils.

B. Increase number of turns of coil.

C. Add type of magnetic core material.

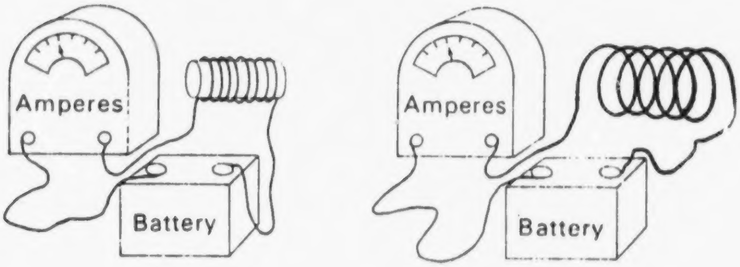
D. Increase diameter of coil.

STRENGTHENING AN ELECTROMAGNET


Amperes
Battery
Battery
Amperes
Battery

Stronger Electromagnet with More Electrical Current

Stronger Electromagnet with More Coils


Amperes
Battery
Amperes
Battery

Stronger Electromagnet with Iron Core

Stronger Electromagnet with Increased Diameter of Coils

Figure A 12.1-11

A ferromagnetic substance that holds magnetic domain alignment well (high retentivity) is used to make permanent magnets.

Permanent and temporary magnetic material

A. Permanent magnetic material

1. Made from certain steel alloys
2. Magnetized with difficulty
3. Retains magnetism well

EXAMPLES OF USES: DC motors, ignition systems, tachometers

On the other hand, ferromagnetic metals that lose magnetism easily (low retentivity) make temporary magnets.

Temporary magnetic material

1. Made from soft iron and iron alloys
2. Magnetized easily
3. Loses magnetism quickly

EXAMPLES OF USES: Relay coils, transformer cores, AC motor field coils

Magnetism plays an important role in many electronic circuits. To further understand magnetic properties for circuits and devices, return to the "Learning Steps" part of the learning guide.

ACTIVITY SHEET

A 12.2

MAGNETIC PROPERTIES

DIRECTIONS: In the figures below, determine the direction of current flow and the magnetic field of a conductor. Draw in the appropriate arrows where needed to show the flow and field.

1.

Electromagnets are an essential part of electric motors, relays, solenoids, and other electrical devices. In these devices, electrical currents and coil windings may be in either direction. In each problem below determine the north and south poles of the electromagnets, and place your answer on the line provided.

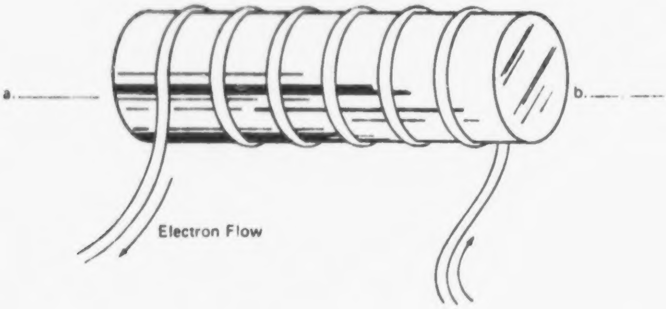


Figure A 12.2-1

2.

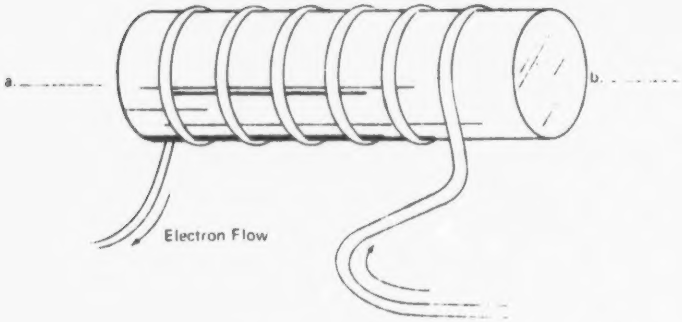


Figure A 12.2-2

ACTIVITY SHEET A 12.2 CONT'D.

3.

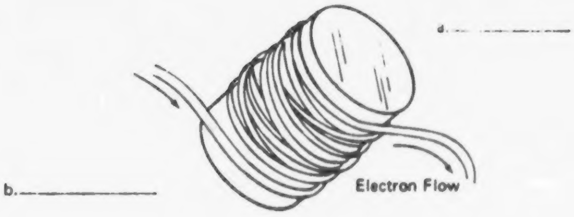

a.
b.
Electron Flow

Figure A 12.2-3

4.

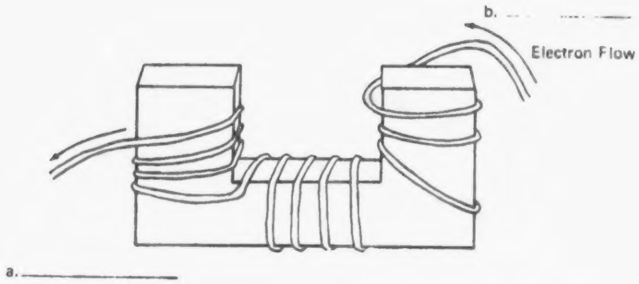

b.
Electron Flow
a.

Figure A 12.2-4

5.

In the Figures below, determine the direction of current flow and the magnetic field of a conductor. Draw in the appropriate arrows where needed to show the flow and field.

6.

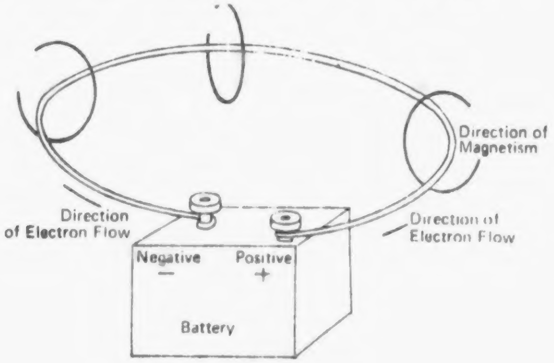

Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
Negative
−
Positive
+
Battery

Figure A 12.2-5

ACTIVITY SHEET A 12.2 CONT'D.

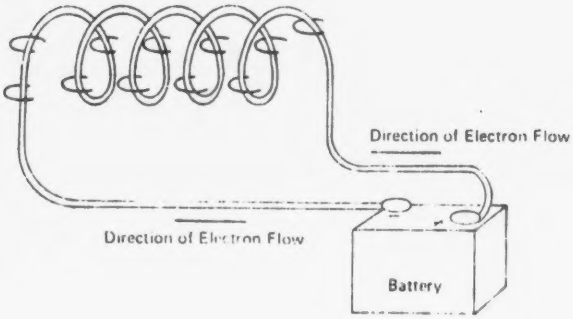

Direction of Electron Flow
Direction of Electron Flow
Battery

Figure A 12.2-6

ACTIVITY SHEET A 12.2

ANSWER SHEET

1. A. North
   B. South
2. A. South
   B. North
3. A. South
   B. North
4. A. North
   B. South
5.

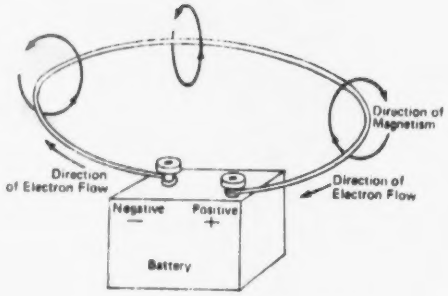

Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
Negative
−
Positive
+
Battery

Figure A 12.2-7

6.

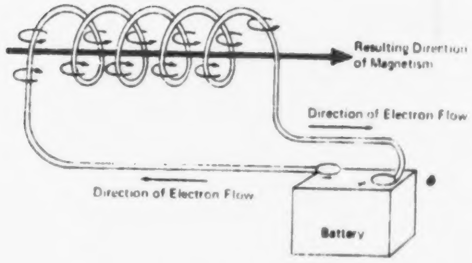

Resulting Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
Battery

Figure A 12.2-8

PROGRAM: ELECTRONICS

TASK: MAGNETIC PROPERTIES

TASK #: A 12.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE __________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT __________

TERMINAL PERFORMANCE OBJECTIVE:

DEFINE MAGNETIC PROPERTIES OF CIRCUITS AND DEVICES.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out 7 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

MAGNETIC PROPERTIES

A 12.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the circuit wired according to the schematic?	Y N
* 2.	Does the circuit function properly?	Y N
3.	Was necessary data recorded?	Y N
* 4.	Was the correct equipment used?	Y N
* 5.	Was the equipment used correctly?	Y N
* 6.	Were safety precautions followed?	Y N
7.	Was the equipment returned to proper storage area?	Y N

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

STUDENT'S SCORE ____

MAGNETIC PROPERTIES

EXAM

A 12.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Magnetic Properties. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer a minimum of 8 out of 10 items correctly, 80%.

MAGNETISM

EXAM

A 12.4

1. Match terms associated with magnetism with their correct definitions. Write the correct numbers in the blanks.

_____ a. Metal material made by mixing two or more metals

_____ b. End of magnet which would point toward earth's North Pole; end into which magnetic lines of force are considered to be entering

_____ c. Magnet created by flow of electricity through coils of wire

_____ d. Shaped like a ring or doughnut

_____ e. Form of the natural pattern, ties, and bonds that holds matter together

_____ f. Having two distinct ends, each with a different electrical or magnetic property

_____ g. Invisible force that results from electrons in motion

_____ h. End of magnet which would point toward the earth's South Pole; end from which magnetic lines of force are considered to be exiting

1. Electromagnet
2. North Pole
3. South Pole
4. Molecular structure
5. Polar
6. Alloy
7. Toroid
8. Magnetism
9. Natural Magnet
10. Synthetic magnet
11. Temporary magnet
12. Retentivity
13. Residual magnetism
14. Reluctance
15. Magnetic Field

_____ i. Magnet produced by passing a current through a coil surrounding a piece of iron or steel; continues only while current is flowing

_____ j. Area where magnetic force can be detected around a magnet; also called magnetic flux

_____ k. Resistance of a magnetic path to the flow of magnetic lines of force

_____ l. Material found in nature which has the quality to attract other materials

_____ m. Ability of material to retain magnetism

_____ n. Magnetism remaining in material after charging force has been removed

_____ o. Magnets that are produced by magnetizing a piece of iron or steel

2. Name six electrical devices utilizing magnetism.

a. ______________________________

b. ______________________________

c. ______________________________

d. ______________________________

e. ______________________________

f. ______________________________

EXAM A 12.4 CONT'D.

3. Identify the direction of magnetic lines of flux by completing the drawings below.

A.

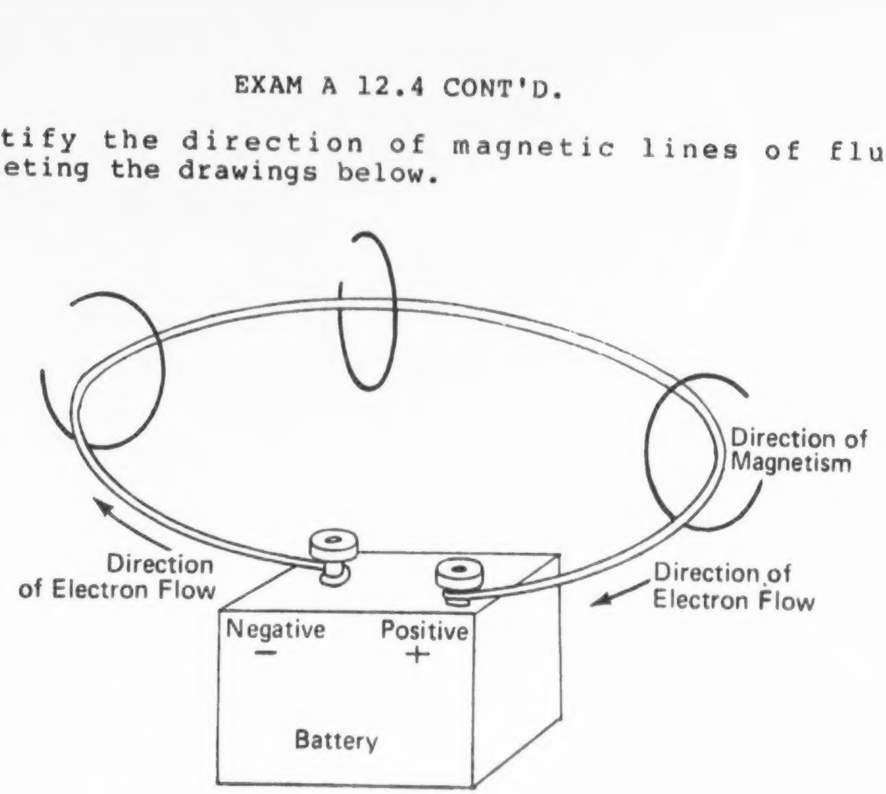

Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
Negative
−
Positive
+
Battery

Figure A 12.4-1

B.

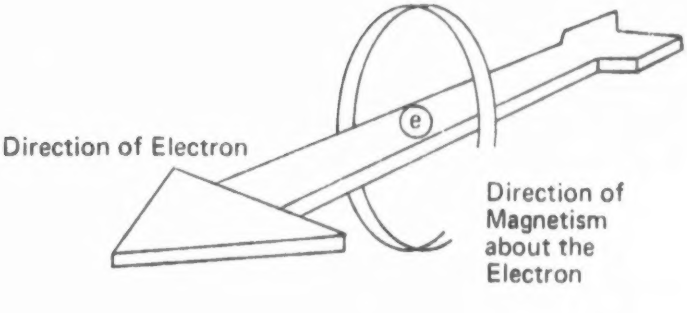

Direction of Electron
e
Direction of Magnetism about the Electron

Figure A 12.4-2

C.

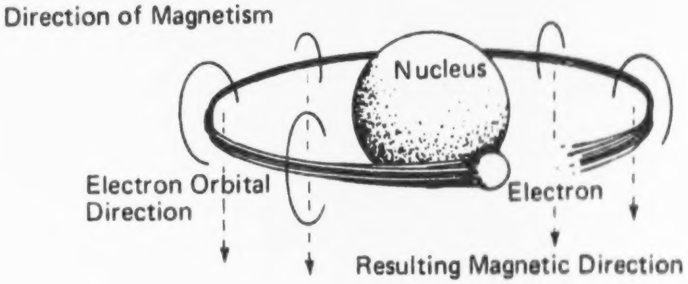

Direction of Magnetism
Nucleus
Electron Orbital Direction
Electron
Resulting Magnetic Direction

Figure A 12.4-3

D.

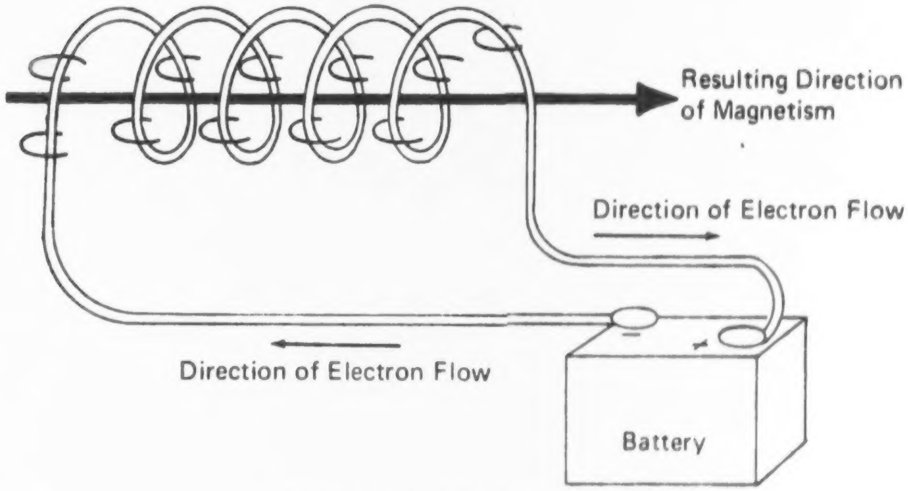

Resulting Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
Battery

Figure A 12.4-4

4. State the left-hand rule for electromagnets.

____

____

____

5. Distinguish between magnetic and nonmagnetic metals. Write an "M" for magnetic metals, and an "NM" for nonmagnetic metals.

_____ a. Copper

_____ b. Molten aluminum

_____ c. Carbon steel

_____ d. Brass

_____ e. Iron

_____ f. Aluminum

_____ g. Stainless steel

_____ h. Tin

6. Discuss in a short paragraph the differences between the structure of magnetic and nonmagnetic materials.

7. Name methods of increasing the strength of an electromagnet.

8. Distinguish between permanent and temporary magnetic material. Write a "P" for permanent magnetic material, and a "T" for temporary magnetic material.

_____ a. Magnetized with difficulty

_____ b. Made from soft iron and iron alloys

_____ c. Retains magnetism well

_____ d. Loses magnetism quickly

_____ e. Magnetized easily

_____ f. Made from certain steel alloys

9. An electromagnet is produced only by alternating current.

A. True
B. False

10. The Magnetic Laws of Nature state: Like poles attract; unlike poles repel.

A. True
B. False

EXAM A 12.4

ANSWER KEY

1.

a.	6	i.	11
b.	3	j.	15
c.	1	k.	14
d.	7	l.	9
e.	4	m.	12
f.	5	n.	16
g.	8	o.	13
h.	2	p.	10

2. Answers should include any seven of the following:

A. Electric motor

B. Electric generator or alternator

C. Relay

D. Solenoid

E. Transformer

F. Computer memory system

G. Tape Recorder

H. Electrical meters

I. Speakers

3. A.

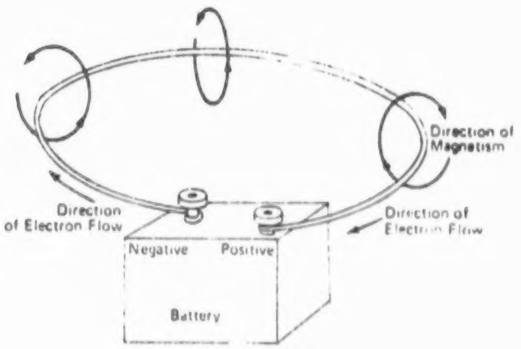
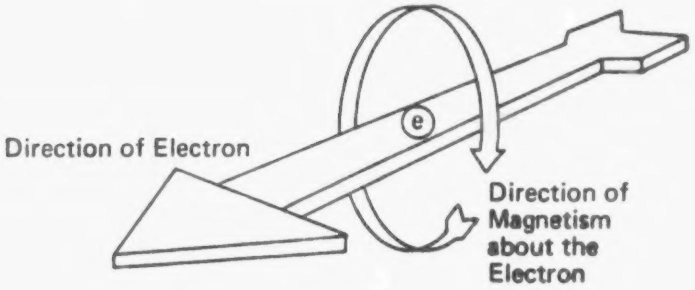

Direction of Magnetism
Direction of Electron Flow
Direction of Electron Flow
Negative
Positive
Battery

Figure 12.4-5

EXAM A 12.4 CONT'D.

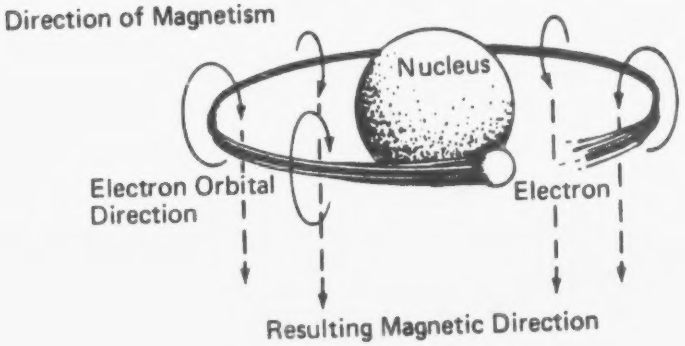
ANSWER KEY

B.



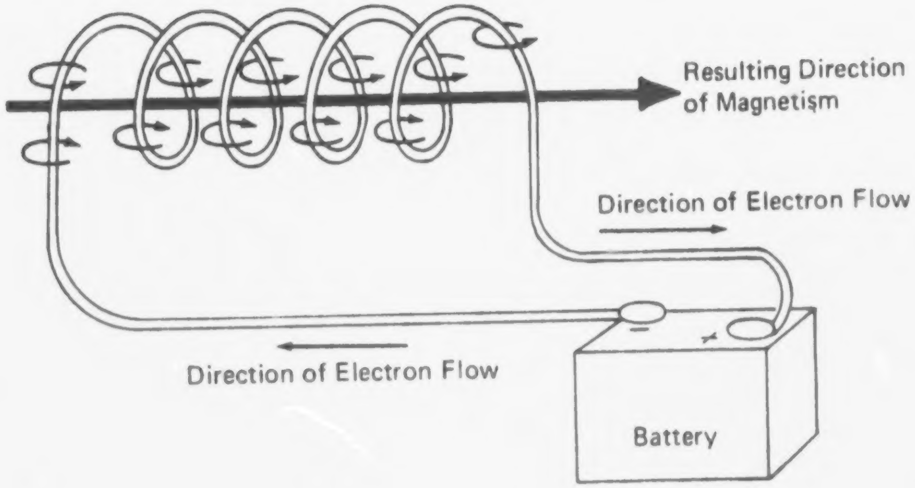
Direction of Electron
e
Direction of
Magnetism
about the
Electron

C.



Direction of Magnetism
Nucleus
Electron Orbital
Direction
Electron
Resulting Magnetic Direction

D.



Resulting Direction
of Magnetism
Direction of Electron Flow
Direction of Electron Flow
−
+
Battery

EXAM A 12.4 CONT'D.

ANSWER KEY

4. If a coil of wire is held in the LEFT hand,the fingers curled around the coils point in the direction of the electron flow, and the extended thumb point in the direction of magnetism, which is called the north pole.

5. a. NM
   b. M
   c. M
   d. NM
   e. M
   f. NM
   g. NM
   h. M

6. Discussion should include

   a. Magnetic materials-Groups of atoms that act as tiny magnets and can move to alignment in one general direction; the net effect is magnetism.

   b. Nonmagnetic materials

      1. Groups of atoms that act as tiny magnets are restricted by their molecular structures from moving into alignment; the net effect is no magnetism

      2. Individual atoms or groups of atoms which have no magnetic polarity at all

7. a. Increase flow of electricity through coils

   b. Increase number of turns of coil

   c. Add type of magnetic core material

   d. Increase diameter of coil

8. a. P

   b. T

   c. P

   d. T

   e. T

   f. P

9. B

10. B

ELECTRONICS

ANALYZING DC CIRCUITS

A 13: RC AND RL CIRCUITS

TASK: Analyze, construct, and troubleshoot RC and RL circuits.

PURPOSE: To understand how combinations of resistance--capacitance, and resistance--inductance perform in a circuit can be beneficial when examining circuits. In this learning guide you will be introduced to RC and RL principles.

OBJECTIVE: Given access to all necessary tools and equipment, you will analyze, construct and troubleshoot RC and RL circuits.

ESTIMATED CLASS TIME: 4 HOURS

RC AND RL CIRCUITS

LEARNING STEPS

A 13

READ:	Information Sheet A 13.1 on "RC and RL Circuits."
READ:	Information on RC and RL circuits from the following resource list.
VIEW:	Audio/Visual material on RC AND RL Circuit. Contact your instructor.
COMPLETE:	Activity Sheet A 13.2 on "RC and RL Circuits."
COMPLETE:	Activity Sheet A 13.3 on "RC and RL Problems."
COMPLETE:	Lab Performance on RC and RL circuits. Contact your instructor for this lab.
COMPLETE:	Performance Checklist A 13.4. Contact your instructor.
REVIEW:	All material covered in this learning guide and information presented by your instructor.
COMPLETE:	Written Exam A 13.5. Contact your instructor.

RC AND RL CIRCUITS

RESOURCES

A 13

1. BASIC ELECTRICITY AND CIRCUIT CONCEPTS: VOL. 1, DC CIRCUITS, Oliva and Dale (Radio Shack: Texas Instrument Learning Center, 1979), 4th Edition. Chapter 1.
2. DC ELECTRONICS (Heathkit Educational Systems, 1984). Units I & II.
3. BASIC ELECTRONICS, Grob (McGraw-Hill, 1984). Chapter 1.
4. INTRODUCTION TO ELECTRICITY AND ELECTRONICS, Bell & Howell Schools (DeVry Institute of Technology, 1984). Chapter 1001.
5. INTRODUCTION TO INDUSTRIAL ELECTRICITY-ELECTRONICS (Oklahoma Trade and Industrial Education).
6. ELECTRONICS: PRINCIPLES AND APPLICATIONS, Badrkhan and Larky (South Western Pub.). Chapter 1.
7. ELECTRICITY ONE-SEVEN, Mileaf (Hayden). Chapter 1.
8. ELECTRONIC COMMUNICATION, Schrader (McGraw-Hill Pub. Co.). 5th Ed. Chapter 1.

INFORMATION SHEET

A 13.1

RL AND RC CIRCUITS

An RL circuit is one that includes both resistance and inductance. There must be at least one resistor and one inductor in an RL circuit, though there can be more of each. A common RL circuit uses a resistor and an inductor in series. A coil is going to have a resistance to offer in a DC circuit.

An RC circuit is one that has both resistance and capacitance. Circuits of this type are used frequently in electronic applications. RC circuits have several unique properties.

SERIES RC CIRCUITS

Given is a circuit that has a capacitor and a resistor in series.

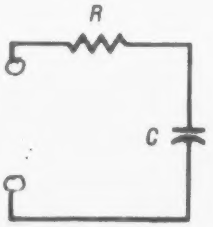


Figure A 13.1A

The effect of RL and RC circuits have on a circuit is determined by the time current flowing in the circuit. This is known as a time constant.

The time constant formula for RC circuits is T = R x C.
(T) = Time constant in seconds
(C) = Capacitance in farads
(R) = Resistance in ohms

The time constant formula for RL circuits is T = L/R.
T = Time constant in seconds
L = Inductance in henries
R = Resistance in ohms

The charging and discharging of a capacitor through a resistor can be expressed through a graph called the Universal Time Constant Graph.

INFORMATION SHEET A 13.1 CONT'D.

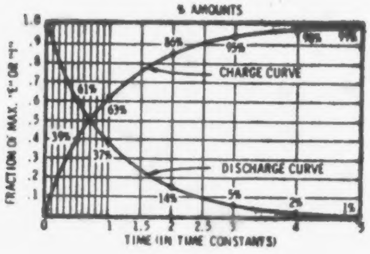


Figure A 13.1B

UNIVERSAL TIME CONSTANT GRAPH (CHARGE) - This graph marks out in detail exactly what percentage of the applied voltage a capacitor will have charged to during specific time intervals after the voltage is applied to an RC circuit. If you know a circuit's time constant, this curve will enable you to accurately predict RC circuit behavior as time goes on.

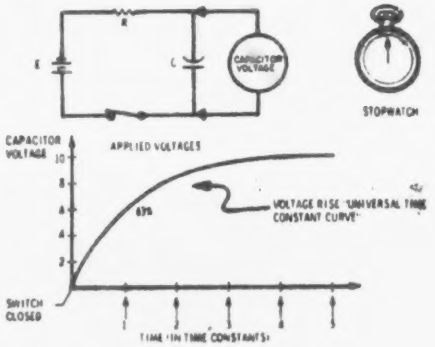

R
E
C
CAPACITOR VOLTAGE
STOPWATCH
CAPACITOR VOLTAGE
APPLIED VOLTAGES
10
8
6
4
2
63%
VOLTAGE RISE "UNIVERSAL TIME CONSTANT CURVE"
SWITCH CLOSED
1
2
3
4
5
TIME (IN TIME CONSTANTS)

Figure A 13.1C

UNIVERSAL TIME CONSTANT GRAPH (DISCHARGE) - When switch, S, is closed, the capacitor discharges. As the stopwatch ticks off the first RC time constant, the capacitor's voltage falls 63% of its fully charged voltage, so that at the end of one RC time constant, the voltage remaining on the capacitor is 37% of its fully charged value. During each successive time constant, the voltage continues to fall 63% of the remaining voltage value. After five time constants, the voltage may be assumed to be zero. Notice this important point: it takes five time constants for a capacitor to

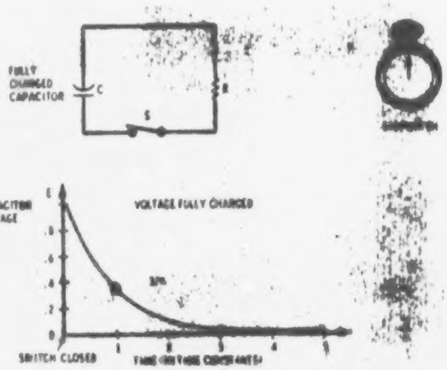
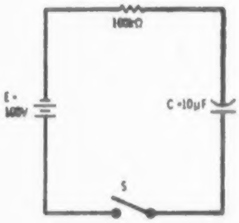

FULLY CHARGED CAPACITOR
C
R
S
CAPACITOR VOLTAGE
E
VOLTAGE FULLY CHARGED
.8
.6
.4
.2
0
37%
SWITCH CLOSED
1
2
3
4
5
TIME (IN TIME CONSTANTS)

Figure A 13.1D

either fully charge or fully discharge. This is an important fact to remember concerning RC circuits.

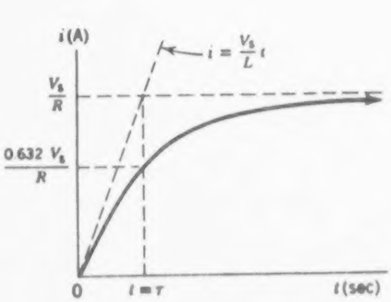
EXAMPLE: RC CIRCUIT DEMONSTRATION - To understand RC circuits more fully, follow the circuit analysis as if you were actually watching the circuit perform. The circuit contains a 10-microfarad capacitor, and a 100-kilohm resistor and a switch, S, as shown. These components will be connected to a 100-volt dc supply. First calculate the time constant for this circuit, using the formula T=RC. Substituting R=100k or $1X10^5$ and C=10 F or $1X10^{-5}$ farads, and multiplying $1X10^{+5}$ and $1X10^{-5}$ gives you $1X10^0$ or 1. so the time constant for this circuit is 1 second.



T = RC
T = 100kΩ X 10μF
T = $1X10^5$ X $1X10^{-5}$
T = $1X10^0$
T = 1 SECOND

Figure A 13.1E

CURRENT RISE IN L/R CIRCUIT - A universal time constant graph can be used to plot current flowing in a circuit versus time, instead of voltage. A capacitor opposes change in voltage across a circuit, where a coil opposes any change in current through a circuit. In series circuits with inductance and resistance, the current rises with a characteristic "time constant" type of behavior.



INFORMATION SHEET A 13.1 CONT'D.

There are several factors affecting time constants.

Factors Affecting Time Constants

In Circuits Containing Resistance and Capacitance (RC)	**In Circuits Containing Resistance and Inductance (RL)**
Time Constant Depends on:	Time Constant Depends on:
1. Circuit Resistance	1. Circuit Resistance
2. Value of Capacitor	2. Value of Inductor

In circuits containing coils and resistors (often termed RL or LR circuits), the time constant will depend directly on the number of henries of inductance present. The more inductance, the longer the time constant, and vice versa. The more series resistance in the circuit, the shorter the time constant will be, and vice versa.

Whether a RC circuit or RL circuit is used, each has a corresponding effect on voltage (RC) and a current (RL) with respect to the time.

You have just been introduced to some basic information on RC and RL circuits. Return to the "Learning Steps" portion of this guide to continue.

ACTIVITY SHEET

A 13.2

RC AND RL CIRCUITS

DIRECTIONS:

Complete each question. DO NOT CONTINUE with any portion of this guide until the Activity Sheet has been completed. If you need any help, see your instructor.

1. A 5-H coil is in series with a 100 resistance, a switch, and a battery. How long will it take for the current to reach 63% of I_{max}?

2. Calculate: T=________

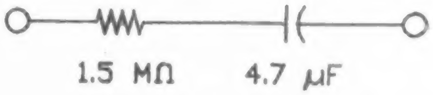


Figure A 13.2A

3. Calculate: T=________

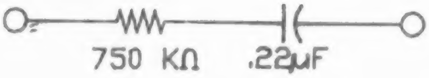


Figure A 13.2B

4. Calculate: T=________

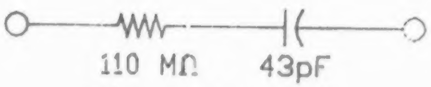


Figure A 13.2C

5. Calculate: T=________

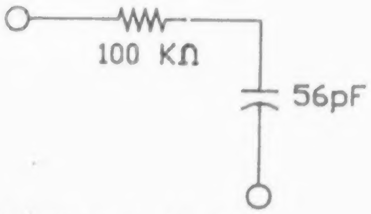


Figure A 13.2D

ACTIVITY SHEET A 13.2 CONT'D.

6. Calculate:

Voltage across the 150k resistor after 2 time constants? ______________

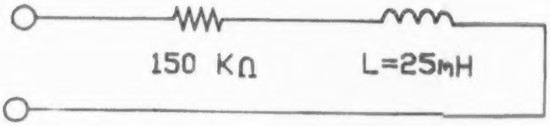

150 KΩ
L=25mH

Figure A 13.2E

7.

I_{max}= ______________

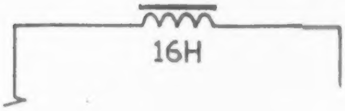


Figure A 13.2F

8.

Circuit time constant= ______________

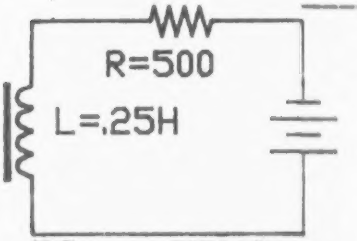


Figure A 13.2G

9.

Voltage across the 100 K resistor after 3 time constants= ______________

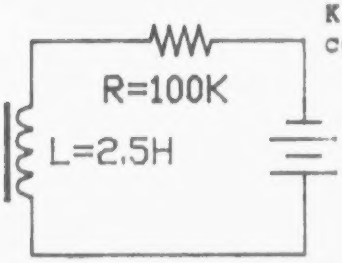


Figure A 13.2H

10. 1 time constant= ________

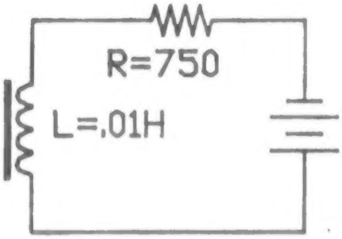


Figure A 13.2I

ACTIVITY SHEET A 13.2

ANSWER SHEET

1. .05 seconds
2. T = 7.05s
3. T = 165 mS
4. T = 4.73mS
5. T = 5.6μS
6. 8.6v
7. 33.3mA
8. 500μS
9. 95v
10. 13.3μS

ACTIVITY SHEET

A 13.3

RC AND RL CIRCUITS

1. If the resistor was 47KΩ and the capacitor was 0.1μF in the circuit of Figure A 13.3-1, how long would it take the voltage across the capacitor to be equal to the supply voltage?

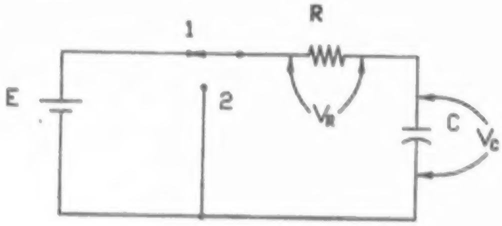


Figure A 13.3-1

2. How long would it take for V_C to equal the supply if the capacitor's value was changed to 10μF?

3. Use the same values of R and C as question 2. What will be the voltage across the capacitor 1 second after the switch is placed in position one? Note E = 1.5 volts.

4. What value of current will be flowing 1 second after the switch is placed in position 1. E = 1.5 V.

5. What is the voltage across the resistor at this point in time? (Same time reference as questions 3 & 4)

6. If the resistance is 220Ω and the inductance is 1.5 H in the circuit of Figure 2, what will be time required for maximum current to flow in the circuit?

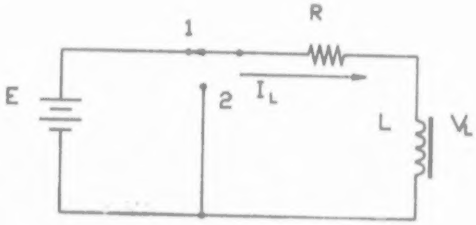


Figure A 13.3-2

ACTIVITY SHEET A 13.3 CONT'D.

7. How much current will flow 5 m Sec after the switch is placed in position 1. (Fig. A 13.3-2) E = 3 volts. R = 220Ω L = 1.5H

8. What will be the voltage across the inductor with the same time and switch connections as question 7? V_L = ?

9. What is the voltage across the resistor at this same point in time? (5 ms)

10. What will be the voltage across the inductor 1 m second after the switch in Figure A 13.3-2 is placed in position 2?

ACTIVITY SHEET A 13.3

ANSWER SHEET

1. $\tau = R \times C = 47K\Omega \times 0.1\mu F = 4.6$ mSeconds

   5 = Full supply voltage $5 \times 5.7 \times 10^{-3} = 23.5$ m Sec

2. $\tau = R \times C$ $47K\Omega \times 10\mu F = 470$ mSeconds $\times 5 = 2.35$ seconds

3. $\tau = R*C = 47K\Omega \times 10\mu F = 470$ mSec

   $V_C\ (t) = E\ (1 - e^{-t/\tau})\ V_C\ (t) = 1.5\ (1 - e^{-1s/.47s})$

   $V_C\ (t) = 1.5\ (1 - e^{-2.1277}) = V_C\ (t) = 1.5\ (1 - .119)$

   $V_C\ (t) = 1.5\ (.881) = 1.32$ volt

4. $i_C\ (t) = \frac{E}{R} e^{-t/\tau} = \frac{1.5}{47K} e^{-1s/.47s} = \frac{1.5}{47 \times 10^{+3}} e^{-2.1277}$

   $(31.915 \times 10^{-6})\ e^{-2.1277} = (31.915 \times 10^{-6}) \times .119 = 3.8$ A

5. $V_R\ (t) = E_e{}^{-t/\tau} = (1.5)e^{-1s/.47s}$

   $= (1.5)e^{-2.1277} = 1.5e\ .119$

   $V_R = .1785$ volts or $V_R = E - V_C = 1.5 - 1.32$ .18 V

6. $\tau = L/R = \frac{1.5H}{220} = 6.818$ mSec. Max = 5 = 5x6.81 ms
   Max i = 34.09 mSec

7. $\tau = L/R = \frac{1.5H}{220} = 6.818$ mSec.

   $I_m = E/R = 3/220 = 13.636$ mA;i (5ms) $= I_m\ (1 - e^{-t/\tau})$

   $i\ (5\ ms) = 13.636 \times 10^{-3}\ (1 - e\ \frac{-5 \times 10^{-3}}{6.818 \times 10^{-3}})$

   $= 13.636 \times 10^{-3}\ (1 - e^{-733.4 \times 10^{-3}}) =$

   $i\ (5\ mS) = 13.636 \times 10^{-3}\ (1 - .48) = 13.636 \times .519$

   = 7.086 mini amps

ACTIVITY SHEET A 13.3 CONT'D.

8. V_L = (5 ms) = E $e^{-t/\tau}$ = 3 e^{-5} /6.818 mS

   = 3 $e^{-733.335}$ x 10^{-3}

   V_L (5 mS) = 3 x .4803 = 1.44 volts

9. V_R (t) = E 1 - $e^{-t/\tau}$ or V_R = E - V_L = 3 - 1.44 = 1.56 V

10. V_L (t) = E $e^{-t/\tau}$ V_L (1ms) = 3 $e^{-1ms/6.818\ ms}$ = 3 $e^{-.1467}$=

    V_L (1ms) = 3 x .864 = 259 V

PROGRAM: ELECTRONICS

TASK: RC AND RL CIRCUITS

TASK #: A 13.4

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

ANALYZE, CONSTRUCT, AND TROUBLESHOOT RC AND RL CIRCUITS.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out 7 points or 85% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 85%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

RC AND RL CIRCUITS

A 13.4

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the circuit wired according to the schematic?	Y N
* 2.	Does the circuit function properly?	Y N
3.	Was necessary data recorded?	Y N
* 4.	Was the correct equipment used?	Y N
5.	Was the equipment used correctly?	Y N
* 6.	Were safety precautions followed?	Y N
7.	Was the equipment returned to proper storage area?	Y N

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

STUDENT'S SCORE ____

RC AND RL CIRCUITS

EXAM

A 13.5

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on RC AND RL Circuits. Each of the questions or incomplete statements is true or false. Place the letter associated with that choice (A or B) in the numbered blank space on your Answer Sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer a minimum of 8 out of 10 items correctly, 80%.

RC AND RL CIRCUITS

EXAM

A 13.5

1. An RC contains both resistance and inductance.

   A. True
   B. False

2. An RL circuit contains both capacitance and inductance.

   A. True
   B. False

3. A capacitor will be charged to 85% of its maximum charge in an RC charging circuit after only 1 time constant.

   A. True
   B. False

4. A universal time constant can be used to plot RC or RL values vs. time.

   A. True
   B. False

5. Two factors that affect a RL time constant is the 1) circuit resistance 2) value of the inductor.

   A. True
   B. False

6. The capacitive time constant is defined by $T=\frac{R}{C}$.

   A. True
   B. False

7. When evaluating a capacitive time constant, the R in the equation is in ohms and the C is in farads. As a result T is in milliseconds.

   A. True
   B. False

8. Find the voltage across the 750 ohm resistor after $25\mu S$.

   V_R=____________________.

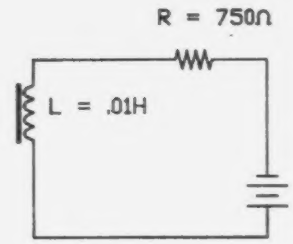


Figure A 13.5-1

9. How long will it take the capacitor to reach full charge?

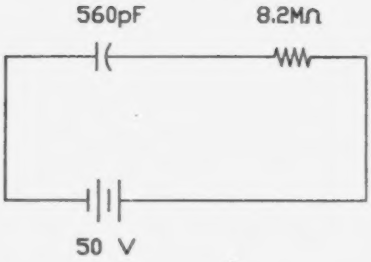

560pF
8.2MΩ
50 V

Figure A 13.5-2

10. Calculate: T=______________

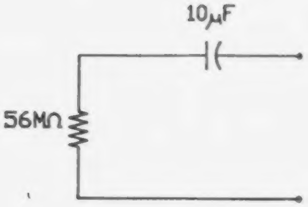


Figure A 13.5-3

EXAM A 13.5

ANSWER KEY

1. B
2. B
3. B
4. A
5. A
6. B
7. B
8. 17 volts
9. 23mS
10. 560s

ELECTRONICS

ANALYZING AC CIRCUITS

B 1: AC WAVEFORM

TASK: Calculate and measure AC waveform time periods, frequencies, wavelengths, and voltages.

PURPOSE: Up to this point, your study of electronics has dealt with DC voltages and current, which are usually constant in reference to time and magnitude. This learning guide will acquaint you with signals (voltages and currents) which vary in magnitude (value) and time. After you complete this learning guide, you should understand most of the characteristics of AC waveform, particularly those of a sine wave.

OBJECTIVE: Given a written exam and denied access to all reference materials, you will calculate and measure AC waveform time periods, frequencies, wavelengths, and voltages. To master this task, you must score 80% on a written examination.

ESTIMATED CLASS TIME: 5 HOURS

AC WAVEFORMS

LEARNING STEPS

B 1

READ:	Information Sheet B 1.1 on "AC Waveforms."
READ:	Information on AC voltage and current, or time-varying signals, in one or more of the resources listed below.
COMPLETE:	Activity Sheet B 1.2 and B 1.3 on "AC Waveforms."
COMPLETE:	Lab Performances on AC waveforms. Contact your instructor.
COMPLETE:	A review of all the material you have studied on AC waveforms.
COMPLETE:	Written Exam B 1.4 on "AC Waveforms." Contact your instructor.

AC WAVEFORMS

RESOURCES

B 1

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1984). 5th ed.
2. Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). 5th ed.
3. Badrkhan and Lark, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984).
4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS (McGraw-Hill, 1984). 2nd ed.
5. AC ELECTRONICS (Heath Company, 1982). Nineteenth Printing.

INFORMATION SHEET

B 1.1

AC WAVEFORMS

Most of your experience up to this point has been with DC types of signals, that is, signals which do not vary with reference to time. A large category of signals (voltages and currents) might be classified as "time varying" that is, signals which change magnitude (value) with reference to time. This category of time varying signals can be further divided into classifications of step signals, pulse signals, and periodic signals. The last classification can be further divided into the square wave, sine wave, triangle wave, and the sawtooth wave. This learning guide will concentrate on the sine wave signal, and leave the rest of the time varying signals to your text or reference book.

AC is short for "alternating current." The name "alternating" refers to the fact that the current alternates (flows) first in one direction, then in the other direction. Unlike DC, or direct current, AC is constantly changing its magnitude as well as its polarity. When discussing alternating current, a person is usually talking about a sinusoidal type of waveform. The term "sine" is used for "sinusoidal." Figure B 1.1-1 is a graphical representation of an AC waveform produced by an alternating current (AC) generator.

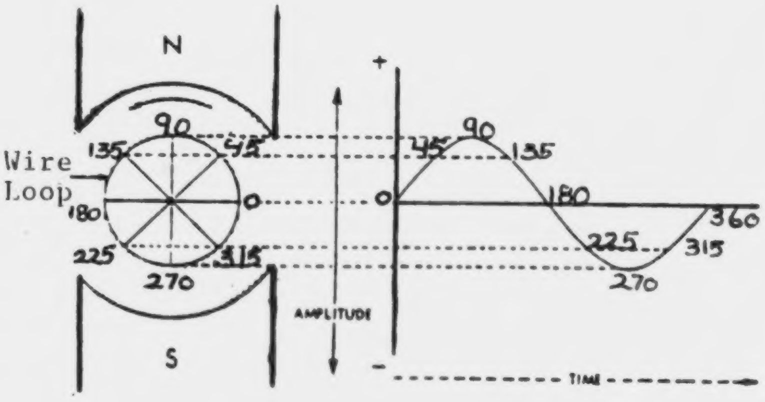


Figure B 1.1-1

If you study the graph or "waveform," you will see that the current rises to a positive value after a period of time, and then falls through zero and changes direction (rises toward maximum negative), and again falls to zero. The graph is of one complete cycle of the generator, which has two complete alternations. Not all sine waves have to be produced from an AC generator; they can also be produced by electronic circuits called oscillators. The sine wave is one of the most important of the periodic waveforms, because of its use by utility companies to provide electrical power.

In order to discuss the AC sine wave, it will be necessary to define some terminology used to describe its values and characteristics. This task may best be accomplished by looking at Figure B 1.1-2, which details the parts of a sine wave.

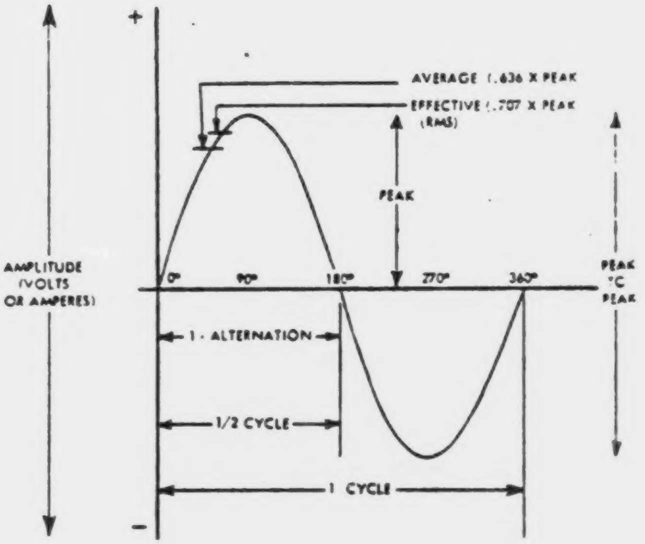

+
AVERAGE (.636 X PEAK
EFFECTIVE (.707 X PEAK
(RMS)
PEAK
AMPLITUDE
(VOLTS
OR AMPERES)
0°
90°
180°
270°
360°
PEAK
TO
PEAK
1 - ALTERNATION
1/2 CYCLE
1 CYCLE
-

Figure B 1.1-2

The vertical axis of the sine wave represents the signal's value in volts or amps, depending whether you are discussing a current or a voltage. The horizontal axis is representative of time, and indicates the frequency of occurrence. The first term we will cover relates to the maximum amplitude of the waveform and is called the "peak-to-peak value." A second term is the "peak value," which represents the maximum positive or negative value. A third term is the "effective value," sometimes called the "RMS" value, which is a value equal to .707 of the peak value. The effective value is sometimes equated to the DC value having the same voltage; in other words, a 110 volts AC would be thought of as having the same effect in a heating circuit as 110 volts of DC. A fourth term is the "average voltage," which is to explain 180 degrees of rotation or one positive half cycle of voltage. A "cycle" is considered to be one complete rotation of the generator, or a complete waveform. One cycle is equal to 360 electrical degrees, and can be related directly to time. Many times it will be necessary to convert from one voltage value (peak) to another (effective); this can be accomplished by using the conversion factors given in Table 1.

TABLE 1: AC MEASUREMENT CONVERSION

Conversion From	Multiplication Factor			
	RMS	Average	Peak	Peak to Peak
RMS (effective)	1.000	0.900	1.414	2.828
Average	1.110	1.000	1.570	3.141
Peak	0.707	0.636	1.000	2.000
Peak to Peak	0.354	0.318	0.500	1.000

The time which it takes for one cycle to occur can be calculated if the frequency is known. As an example, let us assume that the frequency of the sine wave is 60 cycles a second; this simply means that 60 of these sine waveforms occur in one second. The time that it takes for one cycle can be found by using this formula, $T=1/f$, where T is the time in seconds and f is the frequency. In our example, f was equal to 60; therefore, the time T will be equal to 1/60 or about 16.6 milliseconds. This formula can also be "twisted" around and used to find the frequency or number of cycles occurring in a second, by stating it as follows: $f=1/T$. Many times you will use this formula and an oscilloscope to find the frequency of an AC waveform.

Not all AC waveforms operate at the line frequency (60 hz.); many occur at much higher frequencies. In radio work, as an example, the sine waves operate at several hundred thousand cycles per second (hertz), and the wavelength of the sine wave needs to be found. The "wavelength" refers to the physical length of the wave in meters or feet. The waveform's length must be calculated for antenna design. Wavelength in meters is calculated using this formula ($\lambda=V/f$) where λ is the symbol for wavelength, V is the velocity of the wave and f is the frequency of the wave. The length of the wave will decrease as the frequency of the wave increases.

A final consideration for sine waves is that of "phase." Phase is used to relate a time relationship between the voltage and the current of a sine wave. In resistive circuits the voltage peaks and current peaks occur at the same time, which is to say the two are in phase with each other. However, as you will discover in later study, the voltage and current can "get out of step" with one another and are said to be out of phase. In some circuits the voltage will reach its peak before the current, and in other circuits the situation will be the opposite. The phase difference is usually related in terms of degrees.

This concludes the information on AC waveforms for this information sheet; however, it is by no means all the information you will need to know about AC or time varying waveforms.

ACTIVITY SHEET

B 1.2

On a separate sheet of paper complete all of the activities called for.

1. Draw a sine wave and label all of its parts.

2. Make the following conversions:

   A. 160 volts peak to effective.
   B. 120 volts effective to peak.
   C. 100 volts peak to peak-to-peak.
   D. 250 volts peak to average.
   E. 1800 volts peak-to-peak to effective.

3. Find the time period for each of these frequencies:

   A. 100 hz.
   B. 1k hz.
   C. 10k hz.
   D. 100k hz.

4. Find the frequency of each of the following time periods:

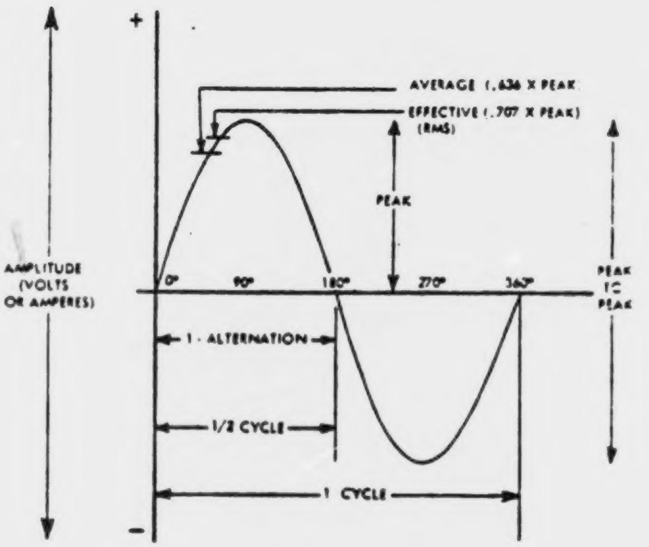
   A. 10 milliseconds.
   B. 10 microseconds.
   C. 10 seconds.

5. Calculate the wavelength for each of the following frequencies: V = the speed of light.

   A. 60 hz.
   B. 6k hz.
   C. 6 Mega hz.
   D. 144 Mega hz.

ACTIVITY SHEET KEY B 1.2

1.


+
AVERAGE (.636 X PEAK
EFFECTIVE (.707 X PEAK)
(RMS)
PEAK
AMPLITUDE
(VOLTS
OR AMPERES)
0°
90°
180°
270°
360°
PEAK
TO
PEAK
1 - ALTERNATION
1/2 CYCLE
1 CYCLE
−

2. A. 113 volts
   B. 169 volts
   C. 50 volts
   D. 159 volts
   E. 636 volts

3. A. .01 seconds
   B. 1 millisecond
   C. 100 microseconds
   D. 1 X 10^{-05} or 10 microseconds

4. A. 100 hz
   B. 100 khz
   C. .1 hz

5. A. 5 million meters
   B. 50,000 meters
   C. 50 meters
   D. 2.08 meters

ACTIVITY SHEET

B 1.3

On a separate sheet of paper complete all of the activities called for.

REVIEW A BASIC TRIGONOMETRY TEXT BEFORE STARTING THIS TASK!

1. Find the sine, cosine, and tangent of angle A in the triangle shown in Figure B 1.3-1.

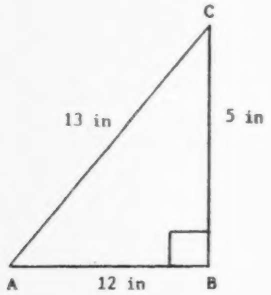


Figure B 1.3-1

2. Find the sine, cosine, and tangent of angle B in the triangle of Figure B 1.3-2.

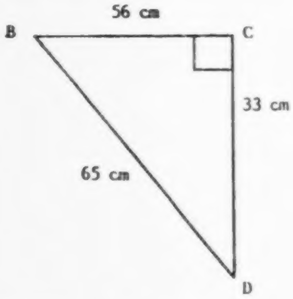


Figure B 1.3-2

3. Find the value of sin 50 degrees.
4. Find the value of tan 30 degrees.
5. Find angle A if cos A = 0.7314.
6. The phase angle in an AC circuit may be represented by angle θ (angle Theta), as shown in Figure B 1.3-3. Find angle Theta and angle B.

ACTIVITY SHEET B 1.3 CONT'D.

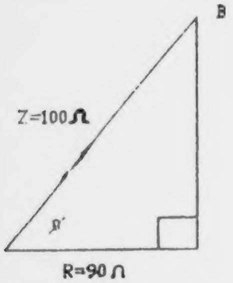


Figure B 1.3-3

7. The relationship among the impedance Z, the resistance R, and the capacitive reactance X_c of an AC circuit is shown in Figure B 1.3-4. Find the impedance Z.

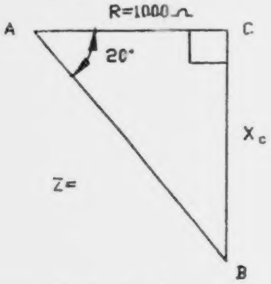


Figure B 1.3-4

8. Find the values of the following functions.

   A. sin 36 degrees
   b. cos 78 degrees
   c. tan 69 degrees

USE FIGURE B 1.3-5 FOR QUESTIONS 9 AND 10

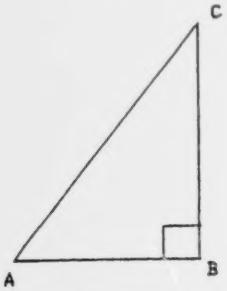


Figure B 1.3-5

9. Find Angle A if BC = 30 and AC = 40.

10. Find angle B if AC = 50 and AB = 100.

ACTIVITY SHEET B 1.3

ANSWER SHEET

1. Hyp. =AC = 13 in.; Opp. Side = BC = 5 in.;
Adj. Side = AB = 12 in.

$\sin \angle A = \frac{\text{opp.}}{\text{hyp.}} = \frac{5}{13} = 0.384.$

$\cos \angle A = \frac{\text{adj.}}{\text{hyp.}} = \frac{12}{13} = 0.923.$

$\tan \angle A = \frac{\text{opp.}}{\text{adj.}} = \frac{5}{12} = 0.417.$

2. Hyp. = BD = 65 cm; Opp. Side = CD = 33 cm;
Adj. Side = BC = 56 cm.

$\sin \angle B = \frac{\text{opp.}}{\text{hyp.}} = \frac{33}{65} = 0.5077$

$\cos \angle B = \frac{\text{adj.}}{\text{Hyp.}} = \frac{56}{65} = 0.8615$

$\tan \angle B = \frac{\text{opp.}}{\text{adj.}} = \frac{33}{56} = 0.5893$

3. $\sin 50^\circ = 0.7660.$

4. $\tan 30^\circ = 0.5774.$

5. $\cos \angle A = 0.7314$; use calculator: $\angle A = 43^\circ$.

6. hyp. = Z, 100 Ω $\qquad$ $\cos \theta = \frac{\text{adj.}}{\text{hyp}} = \frac{90}{100} = 0.9000$
adj. side $\angle\theta$ = R, 90 $\qquad$ $\angle\theta = 25^\circ$ (nearest angle)
$\angle B = 90^\circ - \angle\theta$ $\qquad$ $\angle B = 90^\circ - 25^\circ = 65^\circ$

7. $\angle A = 20^\circ$ $\qquad$ $\cos A = \frac{\text{adj}}{\text{hyp}}$

Find side = AB $\qquad$ $\cos 20^\circ = \frac{1000}{AB}$ $\quad$ Z = AB
Side known = AC =1000 Ω
AB = hyp. $\qquad$ $\frac{0.9397}{1} = \frac{1000}{AB}$ $\quad$ Z = 1064 Ω

AC = Adj Side $\angle A$ $\qquad$ $AB * 0.9397 = 100$

$AB = \frac{1000}{0.9397} = 1064$

ACTIVITY SHEET ANSWER KEY B 1.3 CONT'D.

8. Sin 36° = 0.58779.

Cos 78° = 0.2079.

Tan 69° = 2.6051.

9. Angle A; BC = 30 = opp. side; AC = 40 = adj. side

Tan angle A = $\frac{opp}{adj}$

Tan angle A = $\frac{30}{40}$ = .75 = 48.59°

Approx. 49°

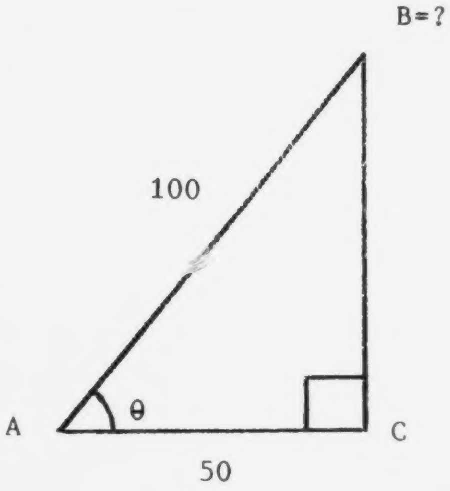
10. Angle B; AC = 50 AB = 100; AC = 50 = Adj Side; AB = 100 = Hyp.

$\angle A$ = Cos A = $\frac{Adj}{Hyp}$

Cos A = $\frac{50}{100}$ = .500 = 60°

$\angle A = 60^{\circ}$

$180^{\circ} - 90^{\circ} - 60^{\circ}$ = B
180 - 150° = $\angle B = 30^{\circ}$



AC WAVEFORMS

EXAM

B 1.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on AC waveforms. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Shade in the letter associated with that choice (A, B, C, D or E) in the numbered blank space on the ANSWER SHEET. Use a #2 pencil to mark your answers. DO NOT WRITE ON THIS TEST! To master this exam you must answer correctly 8 out of 10 items, or 80%.

AC WAVEFORMS

EXAM B 1.4

1. A sine wave is a period type of waveform.

   A. True
   B. False

2. To convert from peak to RMS you would use which of these conversion factors ___________.

   A. .636
   B. 1.414
   C. .707
   D. 2.82

3. Phase refers to ___________.

   A. The total amplitude of the waveform.
   B. The relationship between voltage and current.
   C. The time it takes for one complete cycle.
   D. None of these.

4. The value which is sometimes thought of as the same as a DC value is ___________.

   A. Effective
   B. Average
   C. Peak
   D. Peak to Peak

5. The average value is less than ___________.

   A. Effective
   B. Peak
   C. RMS
   D. All of these

6. The effective value of a sine wave whose peak-to-peak value is 480 volts is ___________.

   A. 170 volts
   B. 339 volts
   C. 288 volts
   D. 153 volts

7. The average voltage value of a sine wave whose effective value is 100 volts is ___________.

   A. 64 volts
   B. 141 volts
   C. 90 volts
   D. None of these

8. If the frequency of a sine wave is 16k hz., the period of the sine wave is ___________.

   A. .0001 second
   B. .1 millisecond
   C. 100 microseconds
   D. All of these
   E. None of these

9. If a sine wave has a time period of 25 microseconds, its frequency is ___________.

   A. .04 hz.
   B. 40K hz.
   C. 4k hz.
   D. None of these

10. The wavelength of a 232 mega hz. sine wave is ___________.

   A. 1.29 meters
   B. .0013 meters
   C. 13 meters
   D. None of these

EXAM KEY B 1.4

1. A
2. C
3. B
4. A
5. D
6. A
7. C
8. E
9. B
10. A

ELECTRONICS

ANALYZING AC CIRCUITS

B 2: CAPACITIVE CIRCUITS

TASK: Use schematics to analyze, construct, and troubleshoot AC capacitive circuits.

PURPOSE: Up to this point in your study of electronics you have primarily dealt with resistors and DC circuits. You will be using capacitors in AC circuits and will be faced with some new concepts, namely capacitance. After you complete this learning guide, you should know what a capacitor is and what effects it has in an AC circuit.

OBJECTIVE: Given access to all necessary tools and equipment, you will use schematics to analyze, construct, and troubleshoot AC capacitive circuits. To master this task you must score 80% on a performance checklist and 80% on a written exam.

ESTIMATED TIME: 12 HOURS

CAPACITIVE CIRCUITS

LEARNING STEPS

B 2

READ: Information Sheet B 2.1 on "Capacitive Circuits."

READ: Information on capacitive circuits in one or more of the following resources listed below.

COMPLETE: Activity Sheet B 2.2 on "Capacitive Circuits."

COMPLETE: Lab Performances on capacitive circuits. Contact your instructor.

COMPLETE: A review of all the material you have studied on capacitive circuits.

COMPLETE: Written Exam B 2.4 on "Capacitive Circuits" and Performance Checklist B 2.3 on "Capacitive Circuits. Contact your instructor.

CAPACITIVE CIRCUITS

RESOURCES

B 2

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1984). 5th ed.

2 Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). 5th ed.

3. Badrkhan and Lark, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984).

4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS (McGraw-Hill, 1984). 2nd ed.

5. AC ELECTRONICS (Heath Company, 1982). Nineteenth Printing.

INFORMATION SHEET

B 2.1

CAPACITIVE CIRCUITS

Capacitive circuits are circuits which have or display capacitive tendencies, which is to say they effect the voltage in the AC circuit. AC circuits will primarily use resistors, inductors, and capacitors. Each of these components will "react" to the AC circuit in a different manner. This learning guide will concern itself with the capacitor and its behavior in an AC circuit.

A capacitor is a device (component) used to store a charge or voltage. It is made from two plates separated by a "dielectric" (insulator). The amount of capacitance measured in farads is determined by the area of the plates, the dielectric material separating the plates, and the distance between the plates (thickness of the dielectric). The farad is a rather large unit of measure, so most capacitors (sometimes referred to as caps) are rated in microfarads or picofarads. The capacitor is also rated as to how much voltage can be placed across its plates before the dielectric breaks down. This rating is usually in working volts DC.

There are many different capacitor types. The type of capacitor is usually determined by its use. Caps used for power supply filtering are usually electrolytic and 1000 microfarad or larger. Capacitors used to bypass noise from Vcc to ground are usually small-value ceramic capacitors. Variable-air capacitors are used in radio tuning circuits. For an idea of the variety of sizes available, consult a catalog for capacitors.

When a capacitor is used in a DC circuit, the capacitor will charge to the DC voltage present, and block any change in voltage. However, when a capacitor is used in an AC circuit it will "react" much differently. The cap's behavior in an AC circuit is called its "reactance" and is measured in ohms. Its capacitive reactive is a function of the cap's capacitance in farads and the frequency of the AC circuit. The capacitive reactance is stated mathematically in the following way: $X_c = 1/2\pi fC$. You can see by looking at the formula that the capacitive reactance is inversely related to the frequency and the capacitance; in other words, as the frequency goes up the capacitive reactance goes down.

Combining capacitors in series or parallel arrangements is just the opposite as it is for resistors. If you put two caps in series, the net capacitance is smaller because of the separation between the plates. If you combine two caps in parallel, the net capacitance is larger because of the area of the plates being increased.

ACTIVITY SHEET

B 2.2

On a separate sheet of paper complete all of the activities called for.

1. What is a capacitor?

2. What is capacitance?

3. What determines capacitance?

4. List five different types of capacitors.

5. What is capacitive reactance?

6. What is the reactance of a 10 microfarad cap in a circuit where the frequency is 1 mega hertz?

7. What is the reactance of the same cap in an AC circuit where the frequency is 100 hertz?

8. If you had a 10 microfarad cap and a 22 microfarad cap in series, the total capacitance would be what?

9. What if the same two caps were arranged in a parallel configuration?

10. Could you use a 1000 microfarad cap rated at 25wvdc in a circuit where the peak voltages were 120 volts? Why not?

11. In a purely capacitive circuit does the voltage lag or lead the current? Why?

12. How much does the voltage lag or lead the current in a purely capacitive circuit?

ACTIVITY SHEET B 2.2

ANSWER SHEET

1. A component used to store a charge.

2. A unit of measure used to determine a capacitor's ability to store a charge; usually rated in farads.

3. The dielectric material, the distance between the plates, and the area of the plates; also the dielectric constant of the dielectric.

4. Ceramic, Mica, Paper, Air, Electrolytic, etc.

5. A measure of the capacitor's reactance to an AC circuit. Measured in ohms and dependent on frequency and capacitance.

6. .0159 ohms

7. 159 ohms

8. 6.875 microfarads

9. 32 microfarads

10. No. Working voltage is too low; the voltage would break through the dielectric.

11. Lags. A cap by its very nature tries to maintain the circuit voltage.

12. 90 electrical degrees

ACTIVITY SHEET

B 2.3

On a separate sheet of paper complete all of the activities called for.

1. What is the electric field intensity between the plates in Figure B 2.3-1 if the source voltage is 20 volts?

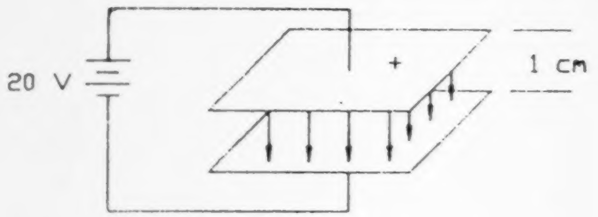


Figure B 2.3-1

2. In Figure B 2.3-2, w =2 cm, l = 1 cm, d = 0.1 cm, and the plates are separated by air. Calculate the capacitance.

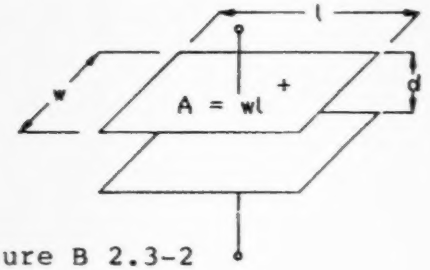


Figure B 2.3-2

3. A capacitor is constructed by gluing two pieces of aluminum foil 2 inches square on either side of a piece of mica 2 mils thick. What is the capacitance?

4. What must be the area of each plate in Problem 3 if a capacitance of 450 pf is desired?

5. What is the maximum voltage which can be applied to the capacitor of Problem 3?

6. What is the total capacitance of a 0.1 microfarad capacitor and a 0.5 microfarad capacitor connected in parallel? In series?

7. Write the equations for V_c, V_r, and i in Figure B 2.3-3 if V_s = 15 volts, R = 500 ohms, and C = 4 microfarads. Calculate enough points to make a plot of each.

ACTIVITY SHEET B 2.3 CONT'D.

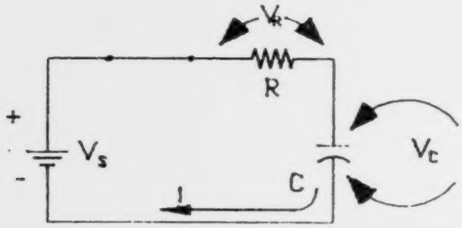


Figure B 2.3-3

8. A 5 microfarad capacitor is charged from zero to 15 volts. What is the energy stored in the capacitor?

9. At what frequency will a 2000 picofarad capacitor have a capacitive reactance of 1 kilo hertz?

10. What value of capacitance must be used to provide a capacitive reactance of 800 ohms at 20 khz?

ACTIVITY SHEET B 2.3

ANSWER SHEET

1. $E = \frac{V}{d}$

E = electric field intensity
V = voltage across capacitor
d =distance between plates in millimeters

$E = \frac{20}{.01m}$

E = 2000 volts/meter

1 cm = .01 m

2. $C\ (F) = \frac{RE_oA}{d}$

Where: E_o is permittivity of Free Space 8.85×10^{-12} MKS
R is a dielect constant
air is = 1.0006

$C\ (F) = \frac{(1)(8.85 \times 10^{-12})(2 \times 10^{-4})}{1 \times 10^{-3}}$

A is area of plates in sq. meters
d is distance between plates in meter

C (F) = 1.77pF

3. C (pF) = 0.225 RA/d

R for Mica = 5

A = 2x2 = 4 sq. in.

d = 2 mils

$C\ (pF) = \frac{0.225(5)(4)}{0.002}$

CpF = 2250 pF

4. 450 oF 2250 = $\frac{1}{5}$;

Therefore, $A = \frac{4m^2}{5}$

$CpF = 450 = \frac{0.225KA}{d}$

$A = 0.8m^2$

$450 = \frac{0.225(5)A}{0.002}$

ACTIVITY SHEET B 2.3 ANSWERS CONT'D.

5. Mica: dielectric strength = $\frac{5000V}{mil.}$

So, $V_{max} = \frac{(5000V)}{mil}$ (2 mil) = 10 K volts

6. In parallel: $C_t = C_1 + C_2 = 0.1\mu F + 0.5\mu F = 0.6\mu F$

In series: $C_t = \frac{C_1 * C_2}{C_1 + C_2} = \frac{0.1\mu F \times 0.5\mu F}{0.1\mu F + 0.5\mu F} = 0.0833\mu F$

7. $V_c = V_s [1-e^{-t/RC}] = 15 [1-e^{-500t}]$

$V_R = Vs\ e^{-t/RC} = 15e^{-500t}$

$i = \frac{V_R}{R} = 30^{e-500t}$ mA

8. $W_{(J)} = \frac{1}{2} C V_o^2$ C is in Farads

V_o is total voltage charge in volts

$W_{(J)} = \frac{1}{2} (5\mu F)(15)^2$ $W_{(J)}$ is energy stored

$W_{(J)} = 562\mu J$

9. $F = \frac{1}{2\pi X_c C} = \frac{1}{2\pi \times 1k \times 2000pF} =$ 79.7khz

10. $C = \frac{1}{2\pi F X_c} = \frac{1}{2\pi \times 20khz \times 800} = 0.01\mu F$

PROGRAM: ELECTRONICS

TASK: CAPACITIVE CIRCUITS

TASK # B 2.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

OBJECTIVE:

Given access to all necessary tools and equipment, use schematics to analyze, construct, and troubleshoot AC capacitive circuits.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 45 minutes and must score at least 17 out of 21 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 45 minutes and must score 17 out of 21 points or 80%, and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

CAPACITIVE CIRCUITS

B 2.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
1.	Was the circuit wired according to the schematic?	Y	N
*2.	Does the circuit function properly?	Y	N
*3.	Was necessary data recorded?	Y	N
4.	Was the correct equipment used?	Y	N
5.	Was the equipment used properly?	Y	N
*6.	Were safety precautions followed?	Y	N
*7.	Was equipment returned to proper storage area?	Y	N

TOTAL POINTS POSSIBLE 21

POINTS NEEDED FOR MASTERY 17

SCORE ______

CAPACITIVE CIRCUITS

EXAM B 2.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on CAPACITIVE CIRCUITS. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Shade in the letter associated with that choice (A, B, C, D or E) in the numbered blank space on the ANSWER SHEET. Use a #2 pencil to mark your answers. DO NOT WRITE ON THIS TEST! To master this exam, you must answer 8 out of 10 items correctly or achieve a score equivalent to 80%.

CAPACITIVE CIRCUITS

EXAM B 2.4

1. Capacitance increases with

   A. larger plate area and greater distance between plates.
   B. smaller plate area and less distance between plates.
   C. larger plate area and less distance between plates.
   D. higher values of applied voltage.

2. Alternating current can flow in a capacitive circuit with AC voltage applied because

   A. of the high peak value.
   B. varying voltage produces charge and discharge current.
   C. charging current flows when the voltage decreases.
   D. discharge current flows when the voltage increases.

3. A simple capacitor can consist of

   A. two metal surfaces separated by a dielectric.
   B. a dielectric and one metal surface.
   C. one metal surface.
   D. two dielectrics separated by a metal surface.

4. The basic unit of capacitance is the

   A. farad.
   B. micro.
   C. ohm.
   D. ampere.

5. In a parallel circuit, if one cap is 10 μf and another is 2 μf, the total capacitance would be

   A. 2 μf.
   B. 8 μf.
   C. 12 μf.
   D. 10 μf.

6. In a series circuit consisting of two capacitors, one at 20 μf and the other at 30 μf, the total capacitance would be

   A. 25 μf.
   B. 20 μf.
   C. 12 μf.
   D. 30 μf.

EXAM B 2.4 CONT'D.

7. Doubling the area of the capacitor plates will cause the capacitance to

   A. remain the same.
   B. decrease to one-half.
   C. increase four times.
   D. double.

8. The capacitive reactance of a 0.1 μf cap at 1000 hz. equals

   A. 1000 ohms.
   B. 1600 ohms.
   C. 2000 ohms.
   D. 3200 ohms.

9. The type of capacitor which may be damaged if the applied voltage reverses polarity is the

   A. ceramic cap.
   B. electrolytic cap.
   C. mica cap.
   D. paper cap.

10. The capacitance needed for a 1000 ohm reactance at 2 megahertz is

    A. 2pf.
    B. 80pf.
    C. 1000pf.
    D. 2000pf.

EXAM KEY B 2.4

1. C
2. B
3. A
4. A
5. C
6. C
7. D
8. B
9. B
10. B

ELECTRONICS

ANALYZING AC CIRCUITS

B 3: AC INDUCTIVE CIRCUITS

TASK:	Using schematics, analyze, construct, and troubleshoot AC inductive circuits.
PURPOSE:	An inductor is a component that plays a major role in the electronic field. Like the capacitor, it has some unique characteristics, such as phase shift. You must understand these characteristics, since most electronics circuits use inductance.
OBJECTIVE:	Given the necessary information on component parts and equipment, you will analyze, construct, and troubleshoot AC inductive circuits. You must score at least 80% on a written exam and laboratory performance.

ESTIMATED CLASS TIME: 8 HOURS

AC INDUCTIVE CIRCUITS

LEARNING STEPS

B 3

READ: Information Sheet B 3.1, "Inductors and Inductance."

READ: Information on inductors and inductance in one or more of the following resources.

COMPLETE: Activity Sheet B 3.2, "Inductors and Inductance."

READ: Information Sheet B 3.3, "Inductors in AC Circuits."

READ: Information on inductors in AC circuits in one or more of the following resources.

COMPLETE: Activity Sheet B 3.4, "Inductors in AC Circuits."

READ: Information Sheet B 3.5, "RL Circuits."

READ: Information on RL circuits in one or more of the following resources.

COMPLETE: Activity Sheet B 3.6, "RL Circuits."

COMPLETE: Activity Sheet B 3.7, "Inductive Problems."

COMPLETE: Lab Performance.

COMPLETE: Lab Performance Checklist B 3.8. Contact your instructor.

COMPLETE: Exam B 3.9.

RECOMMENDED EQUIPMENT

AC power supply
Oscilloscope
VOM or DVM
AF or RF generator
Various inductors and resistors

AC INDUCTIVE CIRCUITS

RESOURCES

B 3

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1984). 5th ed.

2 Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). 5th ed.

3. Badrkhan and Lark, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984).

4. Fowler, ELECTRICITY PRINCIPLES AND APPLICATION (McGraw-Hill, 1984). 2nd ed.

5. AC ELECTRONICS (Heath Company, 1982). Nineteenth Printing.

INFORMATION SHEET

B 3.1

INDUCTORS AND INDUCTANCE

Inductance is the property of a circuit that enables it to oppose any change in current. An inductor is the device that opposes any change in current. Inductor is what we call the device (component) that has the property of inductance.

As you know from previous studies, as current flows through a conductor, magnetic field lines build up around the inductor. The field lines and conductor have the same axis. As the magnetic lines build up, they create opposition to the flow of current. This opposition is called "electromotive force" or "counter emf."

The amount of counter emf is proportional to the rate of change. The faster the rate of change, the greater the emf. It is greatest when the rate of change is at its highest. Refer to Figure B 3.1-1.

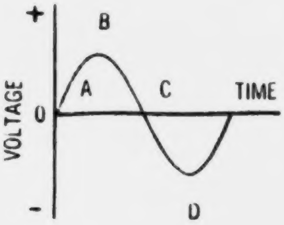


Figure B 3.1-1

The counter emf is higher at points A and C because the rate of change is at its highest. At points B and D the counter emf is low because it stops building and starts to collapse.

When a sine wave is applied to an inductor, the current lags the voltage by 90°. See Figure B 3.1-2. All conductors have some inductance. A straight wire has a small amount; coils of wire have much more.

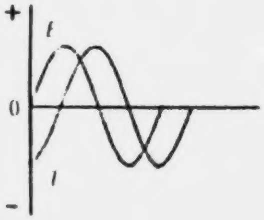


Figure B 3.1-2

Figure B 3.1-3 shows the air core inductor and its symbol, while Figure B 3.1-4 illustrates the iron core inductor and its symbol.

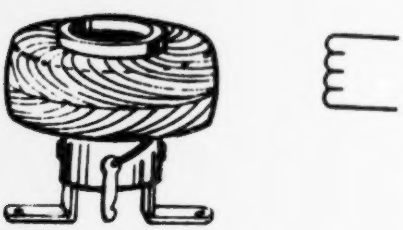


Figure B 3.1-3

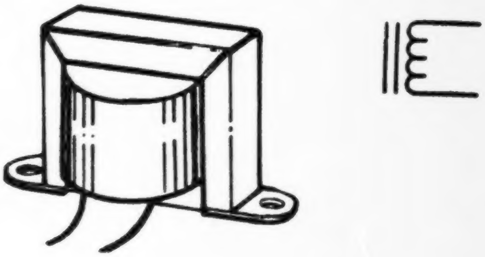


Figure B 3.1-4

The unit of measurement for inductance is the "henry." The abbreviation is H, the symbol is L. Table B 3.1-1 shows the relationship between the henry, millihenry, and the microhenry.

1 henry = 1000 or 10^3 millihenry
1 henry = 1,000,000 or 10^6 microhenry
1 millihenry = 1/1000 or 10^{-3} henry
1 millihenry = 1000 or 10^3 microhenry
1 microhenry = 1/1000000 or 10^{-6} henry
1 microhenry = 1/1000 or 10^{-3} millihenry

Table B 3.1-1

Since inductance is a property of a coil, the standard henry is defined in terms of a standard coil. A coil with one henry of inductance will produce a counter emf of 1 volt when one cycle per second AC current is passed through the coil.

Remember, in an inductive circuit, the current lags by 90°. This is shown in Figure B 3.1-5. In a resistive circuit, the current and voltage are in phase, as shown in Figure B 3.1-6.

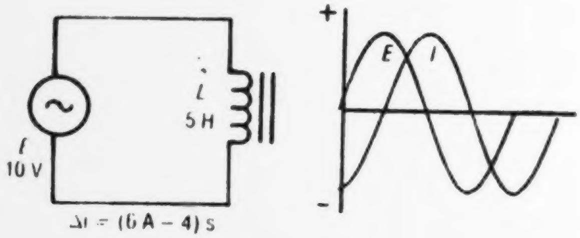


Figure B 3.1-5

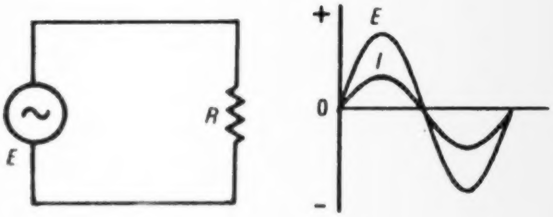


Figure B 3.1-6

Factors affecting the inductance include the number of turns, spacing between the turns, the wire size, the shape of the coil, number of layers of wire, types of windings, the diameter of the coil, length of coil, and core material. This is shown in Figure B 3.1-7.

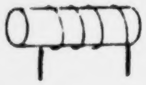
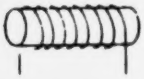
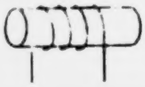
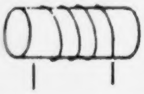
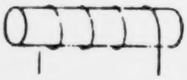
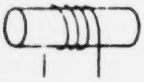
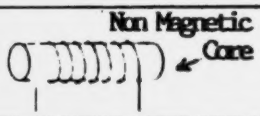
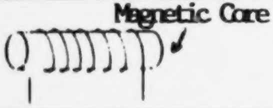
FACTOR	LOW INDUCTANCE	HIGH INDUCTANCE
Number of turns		
Diameter		
Lengths and turns spacing		
Core material		

Figure B 3.1-7

Up to now, the inductors we have discussed were fixed; that is, their inductance was determined by their physical construction. The other type of inductor is the "variable" inductor. Figure B 3.1-8 shows a variable inductor and its symbol.

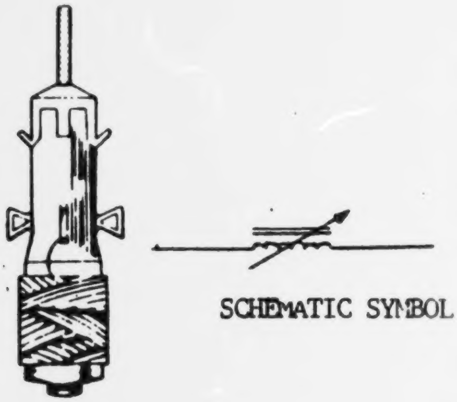


Figure B 3.1-8

ACTIVITY SHEET

B 3.2

1. When current flows through a conductor, a magnetic field is created around the conductor. If the magnetic field is to be made stronger, the current must be ___________________.

2. The electronic component that opposes any change in current is called a(n) _____________________.

3. The property of this component is called _________________.

4. Inductors are also called ______________ and _____________.

5. The unit of inductance is called the __________________.

6. Inductance is designated by the letter ____.

7. It takes 1000 millihenries to make 1 henry, the abbreviation for which is __________.

8. The unit smaller than a millihenry is the ______________ and its abbreviation is ________.

9. 680 mH equals _______________ H.

10. 6800 μH equals _______________ H.

11. A variable inductor usually has a(n) _________________ core.

12. Two basic types of coils are _____________ and ____________.

ACTIVITY SHEET KEY B 3.2

1. Increased
2. Inductor
3. Inductance
4. Coils and Chokes
5. Henry
6. L
7. mH
8. Microhenry, H
9. 0.68H
10. .0068 H
11. Iron
12. Fixed and Variable

INFORMATION SHEET

B 3.3

INDUCTORS AND AC CIRCUITS

THE unique relationship between the applied voltage, the induced voltage and the current in an inductive circuit results in the inductor introducing a phase shift. This is shown in Figure B 3.3-1.

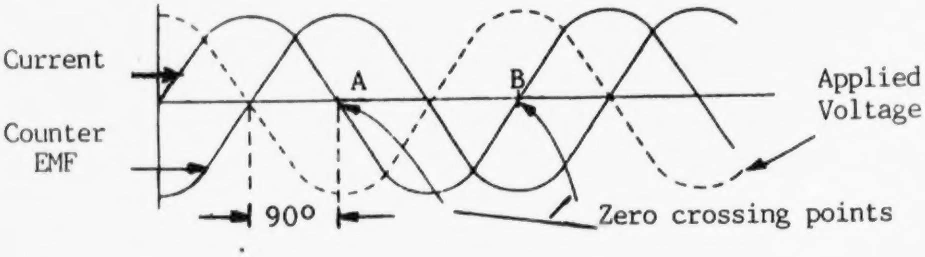


Figure B 3.3-1

The counter emf induced into an inductor by a varying current opposes the applied voltage. As a result, the total effective voltage in the circuit is the difference between the applied voltage and the induced voltage. The greater the inductance, the greater the counter emf. The opposition to the current flow offered by the inductor in an AC circuit is called inductive reactance.

As the frequency of the applied voltage is increased, the rate of change of current increases. This increases the induced voltage. This causes greater opposition to the applied voltage.

Inductive reactance is represented by the symbol X, and is measured in ohms. The formula used to determine inductive reactance is $X_L = 2\pi fL$ ($\pi = 3.14$).

If you are unfamiliar with Lentz's Law, you must use a resource available in your school to obtain an understanding of the subject at this time.

Magnetic flux establishes a magnetic field in space. If two or more inductors are close to each other, their fields will affect each other. This phenomenon is called "mutual induction." This is shown in Figure B 3.3-2. Here you see a coil with AC applied alongside a coil that is not carrying any current. Due to close proximity, an AC voltage will be induced in the second coil.

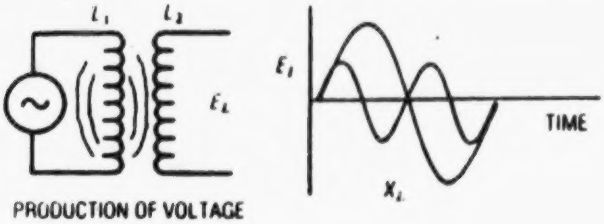


Figure B 3.3-2

To apply the principal of mutual inductance, the relationship of the coils must be known. This relationship is known as the "coefficient of coupling." The symbol of the coefficient of coupling is k.

$$k = \frac{\text{Flux linking coil 1 and coil 2}}{\text{Total flux produced by coil 2}}$$

Once this has been determined, the mutual inductance (Lm) can be calculated by using the formula:

$$Lm = k \quad L_1 \times L_2$$

Up to this point, we have assumed the coil was a perfect coil. That is, the coil has zero resistance. All coils have some resistance. Therefore all inductors are rated according to quality. The symbol for the quality factor is Q. The formula for Q is $Q = \frac{X_L}{R}$

When coils are connected in series with no mutual inductance, total inductance can be determined by the formula: $L_T = L_1 + L_2 + L_3$, etc.

When coils are connected in parallel with no mutual inductance, total inductance can be determined by the formula:

$$L_T = \frac{L \times L}{L + L} \qquad \text{OR} \qquad L_T = \frac{1}{1/L_1 + 1/L_2 + 1/L_3}$$

ACTIVITY SHEET

B 3.4

1. If the current in an inductance is sinusoidal, the induced voltage will be ______________________.

2. If you have coils of 20 mh and 30 mh and the coefficient of coupling is .3, what is the mutual inductance?

3. In a pure inductive circuit, the current ______________ the voltage by ___________________.

4. The frequency is 10 KHz, the inductance is 30 mh; the inductive reactance will be ________________ ohms.

5. The current flowing in an inductive circuit will be influenced by the frequency and inductance. If the frequency is decreased, the current will _______________.

6. If all the lines of force of one coil cut all the turns of the other, the coefficient of coupling will be ______________ .

7. If inductors are connected in series, the total inductance will be a combination of the ________________ of the individual inductance.

ACTIVITY SHEET KEY B 3.4

1. Sinusoidal
2. 7.348
3. Lags, 90
4. 1884
5. Increase
6. One
7. Sum

INFORMATION SHEET

B 3.5

RL CIRCUITS

An RL circuit is one that includes both resistance and inductance. It must have at least one resistor and one inductor, though there can be more of each. Figure B 3.5-1 shows the RL circuit in the RL series circuit. The current lags the voltage by some phase angle between 0° and 90°. The phase angle will depend upon the value of R and L.

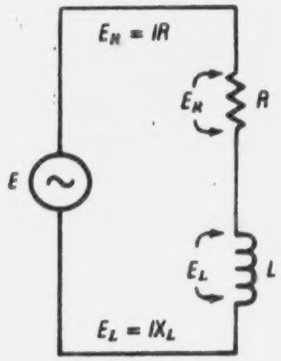


Figure B 3.5-1

To determine the phase angle of the circuit, it is necessary to use a vector diagram (Figure B 3.5-2). Then use the Pythagorean Theorem: $c^2=a^2 + b^2$

$$c = \sqrt{a^2 + b^2}$$

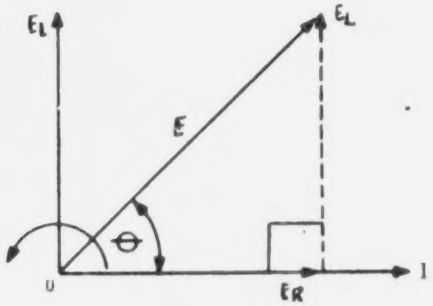


Figure B 3.5-2

Applying this formula to RL circuits, we have:

$$E_A = \sqrt{E_R^2 + E_L^2} \qquad E_L = \sqrt{E_A^2 - E_R^2}$$

$E_R = \sqrt{E_A^2 - E_L^2}$

From this formula you can calculate the three necessary voltages:

The "impedance" (Z) of an RL circuit is the total opposition to current flow offered by both the resistor and inductor. The applied voltage and the total circuit current determines the impedance by using Ohm's Law: $Z = \frac{E}{I}$

The impedance is a function of the resistance and inductive reactance and can be calculated with the formula:

$$Z = \sqrt{(R)^2 + (X)^2}$$

The impedance can be expressed in ohms. The formula can be rearranged to solve for resistance or inductive reactance.

$$R = \sqrt{(Z)^2 - (X)^2}$$

$$X = \sqrt{(Z)^2 - (R)^2}$$

The phase shift in a series RL circuit will be between 0° and 90°. The actual value of phase shift will depend on the value of resistance and inductive reactance. The phase angle (Theta) is shown in Figure B 3.5-3.

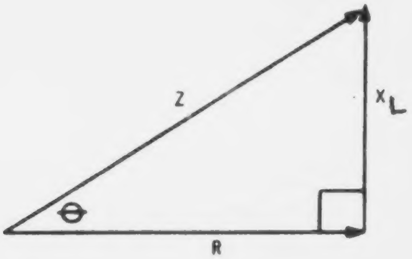


Figure B 3.5-3

As you know, the tangent is the ratio of the opposite side to the adjacent side and is expressed mathematically as:

$$TAN = \frac{X_L}{R}$$

To find the angle itself you use $\theta = \text{ARC TAN} \frac{X_L}{R}$

Since the same current flows in R and L, the phase angle can be expressed as $\theta = \text{ARC TAN}\ \dfrac{E_L}{E_R}$

The power dissipated in a series RL circuit is the power dissipated by the resistor and the resistance of the wire of the inductor. The inductive reactance does not use power. It stores it up, and then returns it. Refer to Figure B 3.5-4 and B 3.5-5.

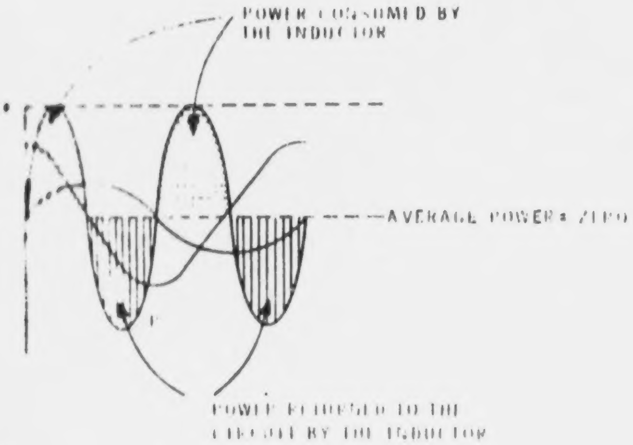


Figure B 3.5-4

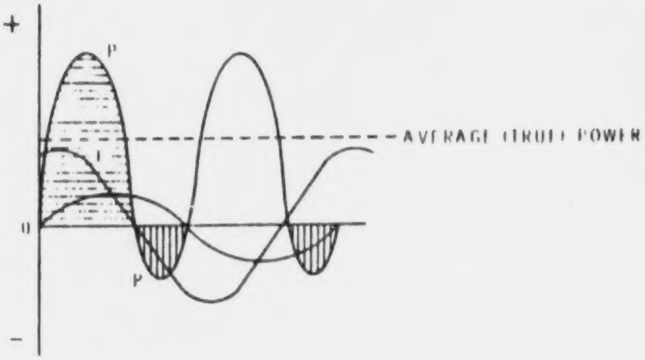


Figure B 3.5-5

ACTIVITY SHEET

B 3.6

1. Total opposition to current flow in an RL circuit is called ______________________.

2. If the resistance in a series RL circuit is increased, the phase shift will ____________________.

3. In all series RL the phase angle is always between ______________ and _______________.

4. In a pure inductive circuit, the current and applied voltage will be ___________________ out of phase.

5. In a series RL circuit, R = 10 ohms and X = 10 ohms; Z = ________________.

6. In Question 5, the phase angle is ____________________.

7. In a series RL circuit, the resistor voltage is 15 volts, the inductor voltage is 20 volts; the applied voltage is _________________ .

8. In the series RL circuit, the impedance is a function of the _________________ and ___________________ .

9. In an inductive circuit, the current _________________ the voltage.

10. In a series RL circuit, the only power dissipated is by the ___________________________ .

ACTIVITY SHEET KEY B 3.6

1. Impedance
2. Lower
3. 0 and 90
4. 90
5. 14.14 ohm
6. 45
7. 25 volts
8. Resistance, Inductive Reactance
9 Lags
10. Resistance

ACTIVITY SHEET

B 3.7

On a separate sheet of paper complete all of the activities called for:

1. The current in a 15 mH inductor changes from 0.0mA to 25mA in a period of 75 msec. What is the induced coil voltage?

2. What must be the inductance of a coil if a current changing at the rate of 950 A/sec. induces a voltage of 85 mV?

3. At what rate must the current change in a 300 mH coil in order to induce a voltage of 100 volts?

4. How fast must a 100 mA current be reduced to zero in order to induce 500 volts in a 250 mH coil?

5. What is the inductance of a 150-turn coil wound on a cylindrical plastic core 150 cm long and 0.9 cm in diameter?

6. Two coils having inductances of 5mH and 10mH are placed close together and have a coefficient of coupling of 0.4. What is the mutual inductance between the coils?

7. What is the coefficient of coupling between two 20 microhenry coils, if their mutual inductance is 3 microhenrys?

8. What is the equivalent inductance of a 3 mH coil connected in parallel with a 6 mH coil?

9. Write the equation for the current in Figure B 3.7-1 if Vs = 20 V, R = 1K ohm, and L = 0.5 H. Calculate the current for t equal to:(a) 100 microseconds, (b) 200 microsecond, (c) 500 microseconds, (d) 2 msec., and plot the results. What is the final value of the current? Plot the voltages across R and L.

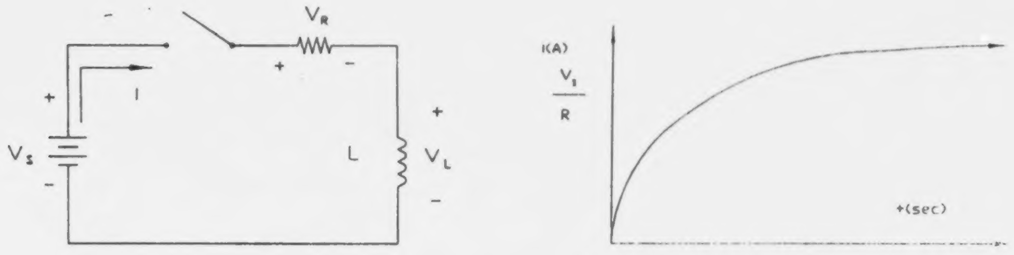


Figure B 3.7-1

10. The switch of Figure B 3.7-2 is held in position A for a long time. Write the equation for the current in 2b. Calculate enough points to accurately plot the voltages across R and L. Vs = 25 volts, R1 = 100 ohms, R2 = 330 ohms, and L = 33mH.

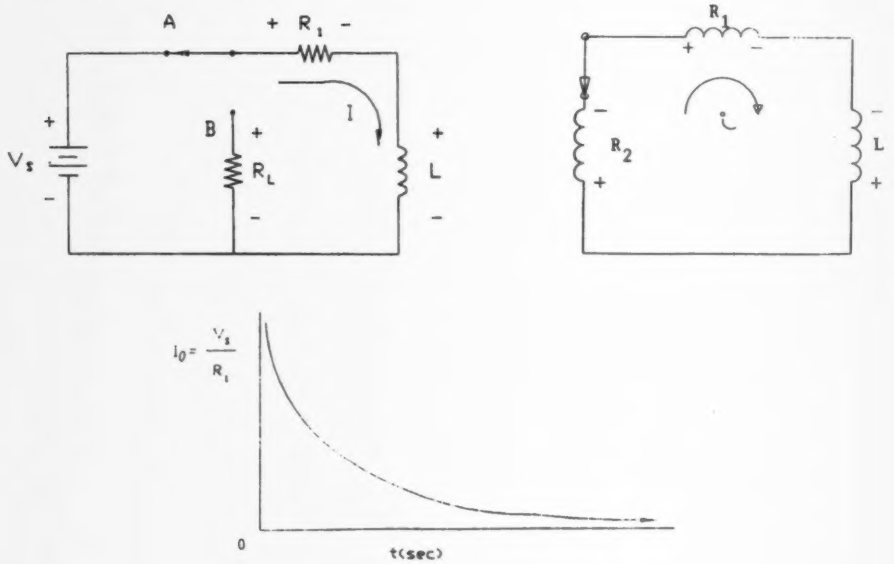


Figure B 3.7-2

11. How long will it take the current in Problem 10 to decay to 50 mA?

12. If the current in a 700 mH inductor increases from zero to 100 mA, how much energy is stored in the field around the coil?

13. What is the inductive reactance of a 4 mH inductor at 25 Khz?

14. At what frequency will a 100 micro H inductor have an inductive reactance of 753 ohms?

15. What must be the inductance of an inductor having an inductive reactance of 1 K ohm at 50 Khz?

ACTIVITY SHEET KEY B 3.7

1. $V = L \frac{di}{dt} = 15 \times 10^{-3} \quad \frac{25 \times 10^{-3}}{75 \times 10^{-3}} = 5 \text{ mV}$

2. $L = \frac{dt}{di} = 85 \times 10^{-3} \quad \frac{1\text{sec}}{950\text{A}} = 89.5 \ \mu\text{H}$

3. $\frac{di}{dt} = \frac{V}{L} = \frac{100}{0.3} = 333\text{A/sec}$

4. $dt = \frac{L}{V} di = \frac{0.25}{500} \quad (0.1) = 50 \ \mu\text{sec}$

5. $L = \frac{\mu N^2 A}{\ell} = \frac{4\pi(10^{-7})(150^2) \cdot \frac{\pi(0.9 \times 10^{-2})^2}{4}}{0.15} = 12 \ \mu\text{H}$

6. $Lm = R\sqrt{L_1 L_2} = 0.4 \sqrt{5 \cdot 10} = 2.83 \text{ mH}$

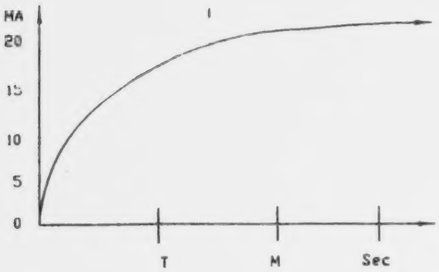
7. $R = \frac{Lm}{\sqrt{L_1 L_2}} = \frac{3 \ \mu\text{H}}{\sqrt{20 \ \mu\text{H} \cdot 20 \ \mu\text{H}}} = 0.15$

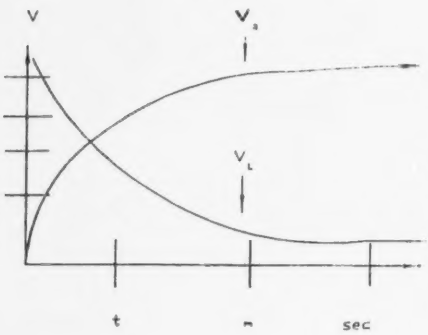
8. $LT = \frac{L_1 L_2}{L_1 + L_2} = \frac{3\text{mH} \quad 6\text{mH}}{3\text{mH} + 6\text{mH}} = 2\text{mH}$

9. $E = \frac{Vs}{R} \left[1 - e - \frac{R}{L} 6 \right] = 20 \left[1 - e^{-2 \times 10^3 t} \right] \text{mA}$

a) 3.63 mA
b) 6.59 mA
c) 12.6 mA
d) 19.6 mA

i Final = 20 mA





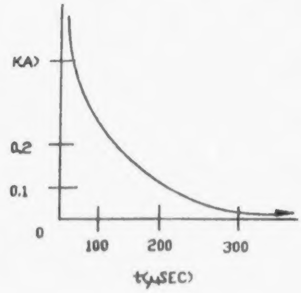
ACTIVITY SHEET B 3.7 ANSWERS CONT'D.

10. $i = I_o e^{\frac{-R}{L} t} = 250 \times 10^{-3} e^{-1.3 \times 10^{4t}}$

or $i = 0.25 e^{-1.3 \times 10^{4t}}$ since $I_o = \frac{V}{R_1} = 250\text{mA}$

$$\frac{R_1 + R_2}{L} = 1.3 \times 10^4$$

$i_{imit} = 0.25$ A $i_{Final} = 0$A



11. $0.05 = 0.25e^{-1.3x10^{4t}}$

Therefore, $t = 123.8$ μS

12. $W = 1/2\ L\ I_o{}^2 = (1/2)\ (0.7)\ (0.1)^2 = 3.5$ mJ

13. $X_L = 2\pi FL = 2\pi\ (25)(10^3)\ 4\text{mH} = 628\ \Omega$

14. $F = \frac{X_L}{2\pi\ L} = \frac{753}{2\pi * (100)\ \mu H} = 1.198$ Mhz

15. $L = X_L/2\pi\ F = 1K/(2\pi * 50\text{ Khz}) = 3.18\text{mH}$

PROGRAM: ELECTRONICS

TASK: AC INDUCTIVE CIRCUITS

TASK # B 3.8

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

OBJECTIVE:

Given the necessary information on component parts and equipment, analyze, construct and troubleshoot AC inductive circuits.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 45 minutes and must score at least 17 out of 21 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 45 minutes and must score 17 out of 21 points or 80%, and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

AC INDUCTIVE CIRCUITS

B 3.8

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
1.	Does the circuit function correctly?	Y	N
*2.	Was the circuit wired according to the schematic?	Y	N
3.	Are the connections correct?	Y	N
*4.	Was the necessary data recorded?	Y	N
5.	Was the correct equipment used?	Y	N
6.	Was the equipment used properly?	Y	N
*7.	Were safety precautions followed?	Y	N
8.	Was the equipment returned to the proper storage area?	Y	N

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

SCORE ______

AC INDUCTIVE CIRCUITS

EXAM B 3.9

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on AC Inductive circuits. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D or E) in the numbered blank space on your answer sheet. Do not write on this test!!!! To master this exam, you must answer 16 out of 20 items correctly, or 80%.

AC INDUCTIVE CIRCUITS

EXAM B 3.9

1. The electronic component that opposes any change in the flow of current is a(n) ___________.

   A. resistor
   B. capacitor
   C. inductor

2. Referring to Question 1, the property of the component is called ___________.

   A. resistance
   B. capacitance
   C. inductance

3. A variable inductor usually has a core made of _________.

   A. air
   B. insulation
   C. iron

4. The unit of measurement of inductance is the _________.

   A. ohm
   B. henry
   C. farad
   D. volt
   E. ampere

5. In a pure inductive circuit, the voltage ____________ the current.

   A. leads
   B. lags
   C. is in phase with

6. If the frequency of the applied voltage is increased, the inductive reactance will _____________ .

   A. increase
   B. decrease
   C. remain constant

7. If none of the lines of force of one coil cut the turns of a second coil, the coefficient of coupling is ________ .

A. 1
B. 0
C. .5
D. 2

8. If the frequency is 20 KHz, and the inductance is 30 mH, the inductive reactance will be _____________ ohms.

A. 1884
B. 188.4
C. 376.8
D. 3768

9. Inductances of 120 mH and 1500 mH are connected in series. The total inductance will be ______ mH.

A. 1620
B. 1512
C. 121.5
D. 2700

10. Two 150 mH coils are connected in parallel. The total inductance will be _________ mH.

A. 300
B. 150
C. 75
D. 450

11. The total opposition in current in an RL circuit is known as ___________________.

A. reactance
B. resistance
C. phase angle
D. impedance

12. If the resistance of an RL circuit is decreased, the phase angle will _______________ .

A. increase
B. decrease
C. stay the same

13. In a series RL circuit the resistor voltage is 18 volts and the inductor voltage is 24. The applied voltage is ________ volts.

A. 42
B. 36
C. 30
D. 34

14. In Question 13, the phase angle is ______________ .

A. 53°
B. 59°
C. 37°
D. 57°

15. In a series RL circuit, R = 24, S = 32; then Z = ____________ ohms.

A. 56
B. 400
C. 560
D. 40

16. In Question 15, the phase shift is __________ .

A. 57
B. 37
C. 53
D. 59

17. In a series RL circuit, the resistance is 30 ohms, the impedance is 50 ohms; the inductive reactance will be _______ ohms.

A. 20
B. 80
C. 58
D. 40

18. In all series RL circuits, the phase angle will be __________ .

A. 45°
B. 53°
C. between 0° and 180°
D. between 0° and 90°

EXAM B 3.9 CONT'D.

19. In a series RL circuit, the power is dissipated in the circuit by the ____________ .

    A. inductor
    B. resistor

20. In a series RL circuit, the resistance is 200 ohms. The inductor is 60 mH, with the applied frequency of 1 KHz. What is the impedance?

    A. 260 ohms
    B. 209 ohms
    C. 427 ohms
    D. 460 ohms

EXAM KEY B 3.9

1. C
2. C
3. C
4. B
5. A
6. A
7. B
8. D
9. A
10. C
11. D
12. A
13. C
14. A
15. D
16. C
17. D
18. D
19. B
20. C

ELECTRONICS

ANALYZING AC CIRCUITS

B 4: TRANSFORMERS

TASK:	Using schematics, analyze and apply principles of transformers to AC circuits.
PURPOSE:	A transformer is a device which plays an important part in electronic technology today. The device uses the principle of mutual inductance to transfer energy from one circuit to another. At the same time it can raise or lower the voltage through transformer action. A transformer has a primary winding and one or more secondary windings.
OBJECTIVE:	Given the necessary information and resources, you will use schematics to analyze and apply the principles of transformers to AC Circuits. You must score at least 80% on a written exam and laboratory performance.

ESTIMATED CLASS TIME: 8 HOURS

TRANSFORMERS

LEARNING STEPS

B 4

READ: Information Sheet B 4.1, "Type and Characteristics of Transformers."

READ: Information on types and characteristics of transformers from one or more of the following resources.

COMPLETE: Activity Sheet B 4.2, "Types and Characteristics of Transformers."

READ: Information Sheet B 4.3, "The Operation of the Transformer."

READ: Information on the operation of the transformer in one or more of the following resources.

COMPLETE: Activity Sheet B 4.4, "The Operation of the Transformer."

COMPLETE: Activity Sheet B 4.5, "Transformer Problems."

COMPLETE: Lab Performance. Contact your instructor.

COMPLETE: Lab Performance Checklist B 4.6.

COMPLETE: Exam B 4.7.

EQUIPMENT

VOM or DVM
Dual-trace oscilloscope
Various transformers
Variable AC power supply
Various resistors

TRANSFORMERS

RESOURCES

B 4

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1984). 5th ed.

2 Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). 5th ed.

3. Badrkhan and Lark, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984).

4. Fowler, ELECTRICITY, PRINCIPLES AND APPLICATIONS (McGraw-Hill, 1984). 2nd ed.

5. AC ELECTRONICS (Heath Company, 1982). Nineteenth Printing.

INFORMATION SHEET

B 4.1

TYPES AND CHARACTERISTICS OF TRANSFORMERS

There are two basic types of transformers, the "air core" and the "iron core." Figure B 4.1-1 shows the schematic symbol of an air core, while Figure B 4.1-2 is the schematic symbol of an iron core. When iron is used, the iron becomes a magnet, thus concentrating the lines of flux, resulting in a more efficient transformer. The iron core is normally made up of laminations. Shown in Figure B 4.1-3 are the two types of laminated cores. Figure B 4.1-3B is the "open" type, with the "shell" type shown in Figure B 4.1-3C.

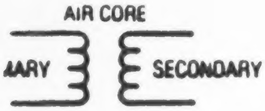


Figure B 4.1-1

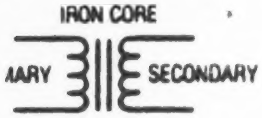


Figure B 4.1-2

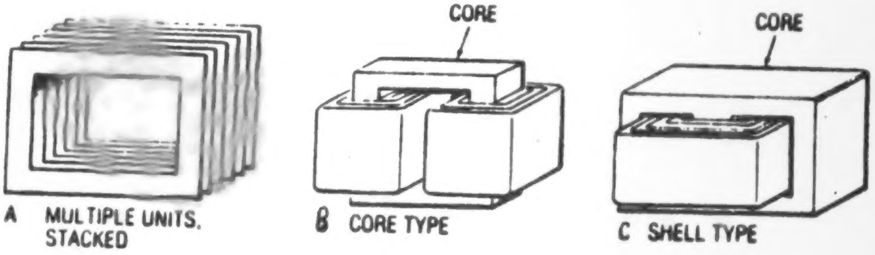


Figure B 4.1-3

When additional precision is required, the "toroidal" core is used. This is shown in Figure B 4.1-4. Another core configuration is shown in Figure B 4.1-5. The basic core is a ceramic form with an iron slug that can be moved in or out of the coil to vary the amount of inductance the core has. The schematic symbol is B 4.1-6.

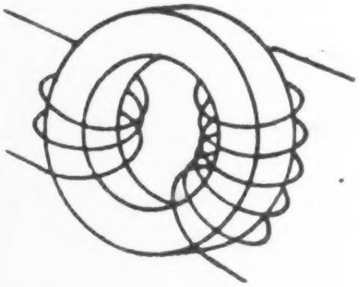


Figure B 4.1-4

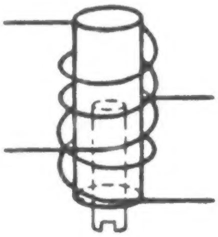


Figure B 4.1-5

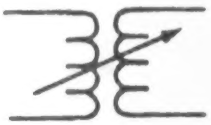


Figure B 4.1-6

As a general principle, the "tighter" the coils are wound, the greater the inductance will be. Examples of "tight" and "loose" wound coils are shown in Figure B 4.1-7. The number of turns in the primary to the number in the secondary is known as the "turns ratio", and expressed by the formula

$$\text{turns ratio} = \frac{N_p}{N_s}$$

For example, a transformer with 300 turns in the secondary and 100 turns in its primary would have a turn ratio of 1:3.

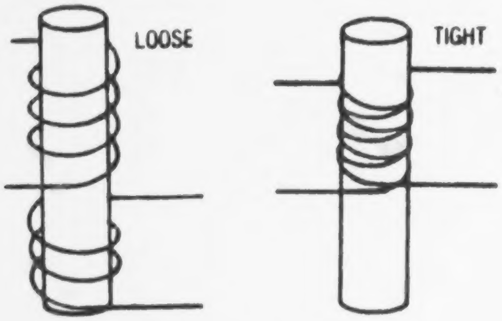


Figure B 4.1-7

The step-up transformer is one in which the output voltage is higher than the input. The voltages in the primary and secondary coils will vary in direct proportion to the turns ratio. This ratio is expressed by the equation:

$$\frac{E_p}{E_s} = \frac{N_p}{E_s}$$

A similar relationship holds true for the current ratio. However, to have equal power in the primary and secondary, the ratio is inversely proportional, and is expressed by the equation:

$$\frac{I_p}{I_s} = \frac{N_s}{N_p}$$

Another type of transformer used to step voltage up or down is the "autotransformer." The autotransformer is one continuous coil with several connections to vary the output voltages. The schematic symbol for the autotransformer is shown in Figure B 4.1-8. "A" is the fixed autoformer, "B" is the tapped autoformer, while "C" is the variable autoformer.

INFORMATION SHEET B 4.1 CONT'D.

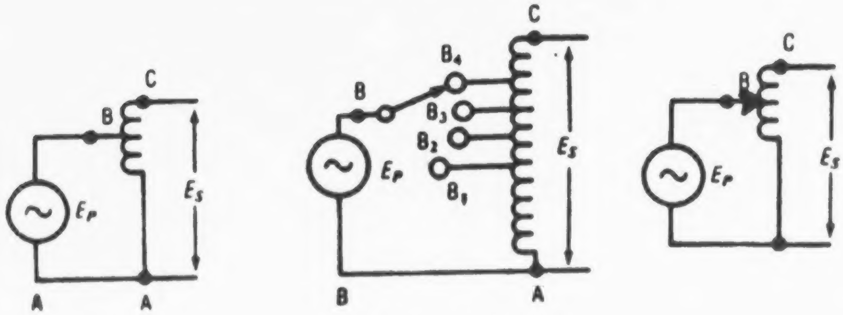

C
B
Ep
Es
A
A
B4
B
B3
B2
B1
Ep
Es
C
B
A
C
B
Ep
Es

Figure 4.1-8

ACTIVITY SHEET

B 4.2

1. The electronic device that couples AC energy from one source to another is called a ________________.

2. As a rule, transformers designed for low frequencies have ________________ cores.

3. When current in the primary increases, the current in the secondary ________________.

4. If a transformer is used to increase an AC voltage, it is a step ________________ transformer.

5. When the mutual inductance must be controlled with more precision, the ________________ type core is used.

6. The voltage ratio of a transformer is in ________________ proportion with the turns ratio.

7. If a transformer is used to lower a voltage, it is called a step ________________ transformer.

8. The current ratio of a transformer is ________________ proportional to the turns ratio.

9. The type of transformer that can step a voltage up or down and has one winding is known as a(n) ________________.

10. The interaction of the magnetic fields of transformer windings are known as ________________ inductance.

ACTIVITY SHEET ANSWERS B 4.2

1. Transformer
2. Iron
3. Decrease
4. Up
5. Toroidal
6. Direct
7. Down
8. Inversely
9. Autotransformer
10. Mutual

INFORMATION SHEET

B 4.3

THE OPERATION OF THE TRANSFORMER

Transformers are versatile devices. They can be used to step-up or step-down voltage, to step-up or step-down current, to match impedance and to produce a 180° phase shift in a signal. They will block DC and pass AC. In this task we will discuss some of these applications.

Whether it is used as a step-up or step-down transformer, one thing to be taken into consideration is transformer losses. Most transformers have an efficiency of about ninety percent. The largest loss occurs in the core. Core losses are of two separate types.

One type of loss is "eddy current loss." These are caused by induced current flowing in the core. This type of loss can be reduced by using a laminated core.

The other type of loss is "hysteresis loss." This type of loss is due to the fact that the magnetic core does not become magnetized by the magnetic field. Every time the magnetic field reverses direction, the domains must also change direction in the core material. As these domains reverse, they must overcome friction and inertia. In doing this they dissipate a certain amount of power in the form of heat. Hysteresis losses increase with frequency; at high frequencies they can become considerable.

Another form of loss is the "copper loss." This loss occurs because of the resistance of the wire in the primary and secondary. This loss can be determined by the formula: $P = I^2R$. The copper loss is proportional to the current squared.

From these losses, more power is applied to the primary than is available to the secondary. To determine the efficiency of a transformer, you use the ratio of input power to output power:

$$\text{Efficiency} = \frac{\text{Power Out}}{\text{Power In}}$$

Depending on the direction of the windings, a transformer will produce a 180° phase shift or no phase shift. Figure B 4.3-1 illustrates this action.

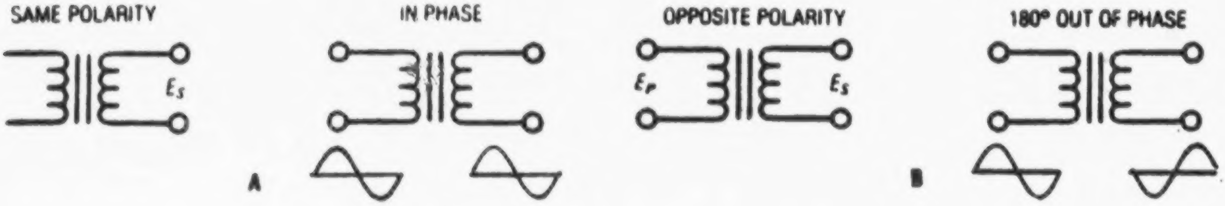

SAME POLARITY
IN PHASE
OPPOSITE POLARITY
180° OUT OF PHASE
E_s
E_p
E_s
A
B

Figure B 4.3-1

Another use of the transformer is impedance matching. It is a very effective device for connecting two circuits with different impedances. The impedance matching formula is:

$$\frac{Z_p}{Z_s} = \frac{(N_p)^2}{(N_s)^2}$$

The formula can be rearranged: $\frac{N_p}{N_s} = \frac{Z_p}{Z_s}$

ACTIVITY SHEET

B 4.4

1. The eddy current losses in a transformer are due to current flowing in the ________________________.

2. Hysteresis losses are due to the power used to realign the ___________________ of the core material.

3. The I^2 R loss is due to the ___________________ of the wire in the primary and secondary.

4. To reduce the I^2 R losses the primary and/or secondary wire can be made ______________________ .

5. The efficiency of a transformer is the ratio of __________ ___________ divided by the ________________________________.

6. A transformer will cause a phase shift of 0° or __________.

7. To determine the impedance ratio of a transformer, all you need to know is the turns ratio.

   A. True
   B. False

8. To determine the impedance of the secondary, all that is necessary is the turns ratio.

   A. True
   B. False

9. With an input voltage of 100 volts, and a turns ratio of 4:1, the output voltage will be _______________.

10. With an output voltage of 400 volts and an input voltage of 2000 volts, the turns ratio is _______________.

ACTIVITY SHEET ANSWERS B 4.4

1. Core
2. Domains
3. Size
4. Larger
5. Power out, power in
6. 180
7. A
8. B
9. 25 V
10. 5:1

ACTIVITY SHEET

B 4.5

ON A SEPARATE SHEET OF PAPER PERFORM ALL OF THE ACTIVITIES CALLED FOR.

1. Draw the schematic symbol for an iron core transformer; an air core transformer.

2. What is the value of L_m in Figure B 4.5-1 if k = 0.2, L_p = 50 micro H and L_s = 100 micro H?

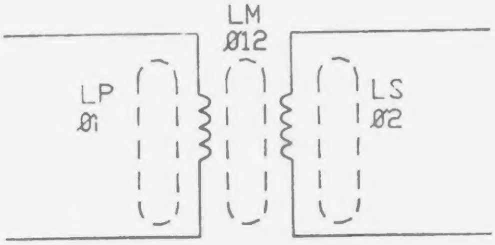


Figure B 4.5-1

3. For a certain transformer, the following are measured: L_m = 1mH, L_p = 3mH, L_s = 10mH. What is the coefficient of coupling?

4. For an ideal iron core transformer having identical windings, $L_p = L_s$. Find the value of L_p if L_m is measured to be 2.7mH.

5. What is the turns ratio of a transformer that has 120 turns on the primary and 3600 turns on the secondary?

6. What is the turns ratio of a step-down transformer whose output voltage is 12.6 V with a primary voltage of 117 V?

7. If the transformer in Problem 6 has a primary current of 100mA, what must the secondary current be?

8. Calculate the primary and secondary power for the transformer in Problems 6 and 7.

9. The transformer in Figure B 4.5-2 has a turns ratio of n = 20. Calculate the load voltage Vl, the load current Il, the primary current I pri., and the power delivered to the load if V_s = 8.5 V and Rl = 2000 ohms.

ACTIVITY SHEET B 4.5 CONT'D.

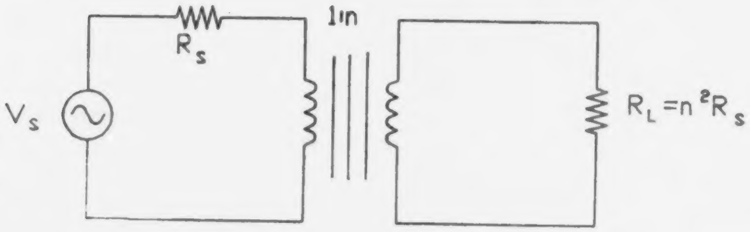


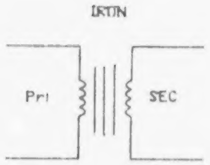
Figure B 4.5-2

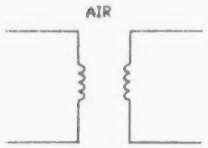
10. Calculate the reflected load and draw the equivalent circuit for the transformer in Problem 9. Check your circuit by calculating the primary current and comparing it with that obtained in Problem 9.

ACTIVITY SHEET B 4.5

ANSWER SHEET

1.





2. $L_m = R\sqrt{L_p\ L_s} = 0.2\sqrt{50*100}$ H = 14.14 μH

3. $R = \frac{Lm}{\sqrt{L_s\ L_p}} = \frac{1}{\sqrt{10*3}}$ mH = 0.18

4. R = 1.0 $L_m = \sqrt{L_p\ L_s} = L_p = L_s = 2.7$mH

5. $\eta = \frac{N_{sec}}{N_{pri}} = \frac{3600}{120} = 30$

6. $\eta = \frac{V_{sec}}{V_{pri}} = \frac{12.6}{117} = 0.108$

7. $I_{sec} = \frac{I_{pri}}{\eta} = \frac{100mA}{0.108} = 928mA$

8. $P_{pri} = P_{sec} = V_{sec}*I_{sec} = 12.6*0.928 = 11.7$ watts

9. $V_L = \eta V_s = 20*8.5 = 170v$

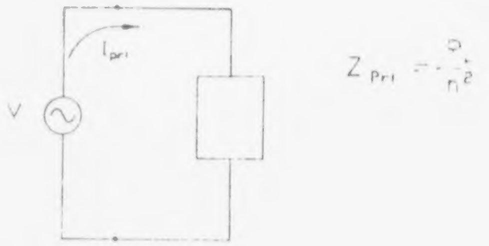
$I_L = \frac{V_L}{R_L} = \frac{170}{2000\Omega} = 85mA$

$I_{pri} = nI^L = 20*85mA = 1.7A$

$p^L = v^{L*}I_L = 170*85mA = 14.45$ watts

10. $\frac{Z_{pri} \quad Z_L =}{\eta^2} \quad \frac{2000}{20^2} = 5\Omega$

Check: $I_{pri} = \frac{V_s}{Z_{pri}} = \frac{8.5}{5} = 1.7A$



PROGRAM: ELECTRONICS

TASK: CAPACITIVE CIRCUITS

TASK # B 4.6

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

OBJECTIVE:

Given the necessary information and resources, you will use schematics to analyze and apply the principles of transformers to AC Circuits.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 7 out of 8 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 45 minutes and must score 17 out of 21 points or 80%, and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

TRANSFORMERS

B 4.6

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Does the circuit function correctly?	Y N
*2.	Was the circuit wired according to the schematic?	Y N
3.	Are the connections correct?	Y N
4.	Was the necessary data recorded?	Y N
5.	Was the correct equipment used?	Y N
*6.	Was the equipment used properly?	Y N
*7.	Were safety precautions followed?	Y N
8.	Was the equipment returned to its proper storage area?	Y N

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

SCORE ______

TRANSFORMERS

EXAM B 4.7

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on transformers. Each of the following questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your ANSWER SHEET. DO NOT WRITE ON THIS TEST! To master this exam you must answer 16 out of 20 items correctly or achieve a score equivalent of 80%.

TRANSFORMERS

EXAM

B 4.7

1. Transformers designed to work at low frequencies generally have __________ cores.

   A. air
   B. iron
   C. ceramic
   D. wood

2. With no load on the secondary, the primary acts like a(n) _______________.

   A. resistor
   B. short circuit
   C. inductor
   D. open circuit

3. If the current in the secondary increases, the primary current _______________.

   A. increases
   B. decreases
   C. doubles
   D. stays the same

4. The interaction of two magnetic fields is called _______________ induction.

   A. primary
   B. secondary
   C. mutual
   D. parallel

5. The voltage ratio of a transformer is _______________ proportional to the turns ratio.

   A. inversely
   B. directly

6. If 40 volts is applied to a transformer which has 100 turns in the primary, and 400 turns in the secondary, the secondary voltage will be __________ volts.

   A. 10
   B. 40
   C. 80
   D. 160

7. In Question 6, the transformer is a _______________ type.

   A. step-up
   B. step-down
   C. autotransformer

8. If maximum power is to be transferred, the impedance of the source must match the impedance of the _______________.

   A. source
   B. primary
   C. load
   D. open circuit

9. The impedance ratio of a transformer is equal to the turns ratio squared.

   A. true
   B. false

10. To match a 1000-ohm source to a 10-ohm load requires a turns ratio of _______________.

    A. 100
    B. 50
    C. 10
    D. 2

11. Eddy current losses can be reduced by using _______________ cores.

    A. copper
    B. air
    C. solid iron
    D. laminated

12. Hysteresis losses are caused by the constant reversal of the _______________ within the core material.

    A. eddy current
    B. I^2 R losses
    C. domains

13. Copper losses are caused by the AC _______________ of the primary and secondary wires.

    A. reactance
    B. resistance
    C. impedance

EXAM B 4.7 CONT'D.

14. Because of various types of losses, the _______________ of a transformer is always less than 100%.

A. current ratio
B. voltage
C. efficiency
D. impedance ratio

15. The input to a transformer is 100 volts @ 1 amp; the output is 400 volts @ 200 milliamps. The efficiency is _______________%.

A. 25
B. 20
C. 80
D. 100

16. A transformer that consists of a single tapped coil is called a(n) _______________.

A. impedance matching transformer
B. autoformer
C. step-up
D. step-down

17. The current ratio of a transformer is proportional to the turns ratio.

A. true
B. false

18. An isolation transformer must always have a turns ratio of 1:1.

A. true
B. false

19. If a transformer has a turns ratio of 3:1, an efficiency of 90%, with 100 volts @ 2 amps on the input, the output will be _______________.

A. 100 watts
B. 180 volts
C. 100 volts @ 3 amps
D. 200 volts @ 2 amp

20. If a transformer has a primary voltage of 300 volts @ 2 amps, and a secondary voltage of 600 volts @.9 amps, the efficiency is _______________%.

A.	54	C.	80
B.	90	D.	99

EXAM B 4.7 ANSWER KEY

1. B
2. C
3. A
4. C
5. B
6. D
7. A
8. C
9. A
10. C
11. D
12. C
13. B
14. C
15. C
16. B
17. B
18. B
19. B
20. B

ELECTRONICS

ANALYZING AC CIRCUITS

B 5: RC AND RL CIRCUITS

TASK: Measure and calculate RC and RL circuit characteristics including integration and differentiation.

PURPOSE: RC and RL circuits are used in many electronic circuits for purposes of timing, filtering, and many other applications. As a technician you will come across many of these circuits and will need to be familiar with their characteristics. After you complete this learning guide, you should be able to measure and calculate RC and RL characteristics.

OBJECTIVE: Given access to all necessary tools and equipment, you will measure and calculate RC and RL circuit characteristics, including integration and differentiation. To master this task you must achieve a score of 80% on a written exam and 80% on a performance checklist.

ESTIMATED CLASS TIME: 12 HOURS

RC AND RL CIRCUITS

LEARNING STEPS

B 5

READ: Information Sheet B 5.1 on "RC and RL Circuits."

READ: Information on RC and RL circuits in one or more of the resources listed below.

COMPLETE: Activity Sheet B 5.2 on "RC and RL Circuits."

COMPLETE: Activity Sheet B 5.3 on "RC and RL Problems."

COMPLETE: Lab Performances on RC and RC circuits. Contact your instructor.

COMPLETE: A review of all the material you have studied on RC and RL Circuits.

COMPLETE: Written Exam B 5.5 and Performance Checklist B 5.4 on "RC and RL Circuits." Contact your instructor.

RC AND RL CIRCUITS

RESOURCES

B 5

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1984). 5th ed.
2. Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). 5th ed.
3. Badrkhan and Lark, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984).
4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS (McGraw-Hill, 1984). 2nd ed.
5. AC ELECTRONICS (Heath Company, 1982). Nineteenth Printing.

INFORMATION SHEET

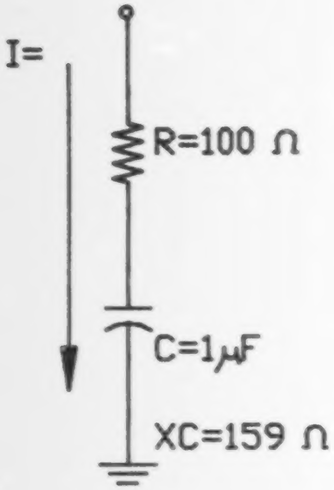
B 5.1

RC AND RL CIRCUITS

An RC AC circuit contains a resistance and a capacitor in a series or parallel configuration, while RL circuits contain a resistance and inductor in series or parallel. The introduction of the capacitor and the inductor cause the circuit voltages and currents to add trigonometrically rather than arithmetically.

A series RC circuit connected to an AC source might look like the one in Figure B 5.1-1. The current in the circuit will be the same and in phase; however, the voltages will be out of phase or step. The circuit will not have a resistance like a DC circuit; it will have what is referred to as an "impedance," and its value is not additive like the DC circuit; it must be found using a special formula. The best explanation might be an example problem solved for Figure B 5.1-1.

E_T = 10VAC F= 1Khz



Impedance = Z

$Z = \sqrt{X_C^2 + R^2}$

$Z = \sqrt{159^2 + 100^2}$

$Z = 188\Omega$

$I = E_T/Z$

$I = 10/188$

$I = 53$ mA

$E_R = I \times R$

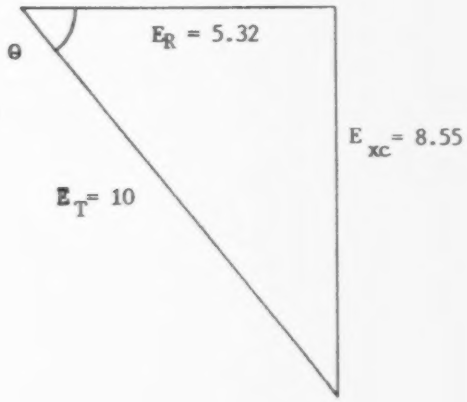
$E_R = 53\text{mA} \times 100\Omega$

$E_R \simeq 5.32$ volts

$E_{XC} = I \times X_C$

$E_{XC} = 53\text{mA} \times 159\Omega$

$E_{XC} \simeq 8.55$ volts



$$X_C = \frac{1}{2\pi FC}$$

$X_C = 159\Omega$

Figure B 5.1-1

INFORMATION SHEET B 5.1 CONT'D.

Figure B 5.1-2 is representative of a parallel RC circuit across an AC source. This circuit is different from the series circuit, in that the voltage is in phase, but the currents are out of phase. The current in this circuit will lead the voltage. Again an example might serve as the best explanation.

$$I_R = \frac{E_T}{R}$$

$$I_R = .1A$$

$$I_T = \sqrt{(Ixc)^2 + (I_R)^2} \qquad TAN\theta = \frac{I_{xc}}{I_R}$$

$$I_T = \sqrt{63mA^2 + 100mA^2} \qquad TAN\theta = 32^\circ$$

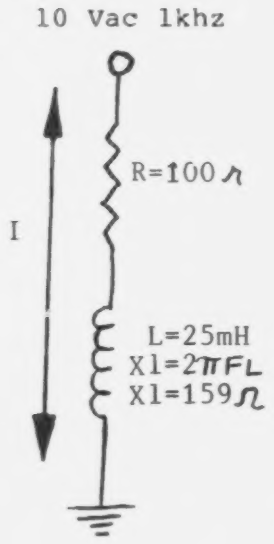
$$I_T = 118mA$$

$$I_{xc} = \frac{10}{159\Omega} \qquad Z = \frac{E_T}{I_T}$$

$$I_{xc} = 63mA \qquad Z = 85\Omega$$

Figure B 5.1-2

A series RL circuit is similar in operation to a series RC circuit; however, the phase angle created by the inductor's reactance causes the voltage to lead the current. This action makes this circuit useful for selective filtering and rf tuning. Figure B 5.1-3 is an example of an RL circuit and its characteristics.



$$I = \frac{E_T}{Z}$$

$$I = \frac{10}{188}$$

$$I = 53mA$$

$$Z = \sqrt{(X_L)^2 + R^2}$$

$$Z = \sqrt{159^2 + 100}$$

$$Z \simeq 188\Omega$$

$$E_R = IxR$$

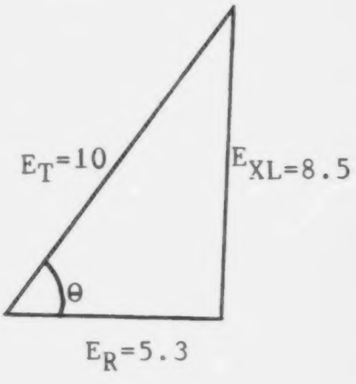
$$E_R = 53mAx100$$

$$E_R = 5.32 \text{ volt}$$

$$E_{XL} = 53mAx159$$

$$E_{XL} = 8.5 \text{ volts}$$

$$I = 53 \text{ mA}$$



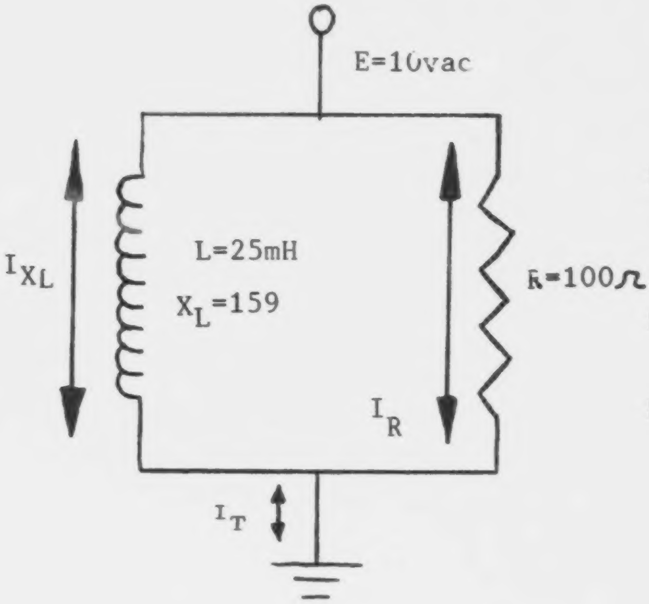
$$TAN\theta = \frac{E_{XL}}{ER}$$

$$\theta \simeq 57.8^\circ$$

Figure B 5.1-3

INFORMATION SHEET B 5.1 CONT'D.

Figure B 5.1-4 is an example of a parallel RL circuit and its calculations and characteristics.


E=10vac
I_{XL}
L=25mH
X_L=159
R=100Ω
I_R
I_T

$$I_T = \sqrt{(I_{XL})^2 + (I_R)^2}$$

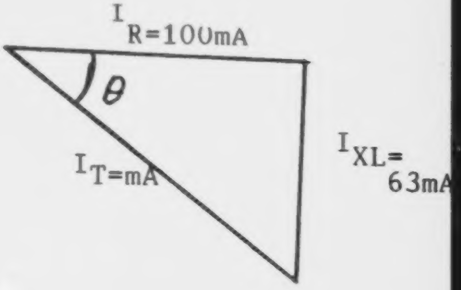
$$I_T = \sqrt{63mA^2 + 100mA^2}$$

$$I_T \simeq 118mA$$

$$Z = \frac{E_T}{I_T}$$

$$Z = \frac{10}{118mA}$$

$$Z \simeq 85\Omega$$


I_R=100mA
θ
I_T=mA
I_{XL}=
63mA

$$TAN\theta = \frac{-I_{XL}}{I_R}$$

$$TAN\theta \simeq -32.2^\circ$$

$$I_{XL} = \frac{E_T}{X_L}$$

$$I_{XL} = \frac{10}{159}$$

$$I_{XL} \simeq 63mA$$

$$I_R = \frac{E_T}{R}$$

$$I_R = \frac{10}{100}$$

$$I_R = 100mA$$

Figure B 5.1-4

Electronic integration is the process of producing an output signal that represents the sum of all the incremental changes in the input signal over a period of time. Remember, the voltage across a capacitor is proportional to the sum of all the instantaneous voltages applied across it. To produce good integration, the time constant (RC) of the circuit must be long compared to the time period (1/f) of the waveform. This is necessary so that the voltage across C represents the sum of all the instantaneous voltages applied to the input over a period of one cycle. Figure B 5.1-5 is an example of a simple integrating circuit.

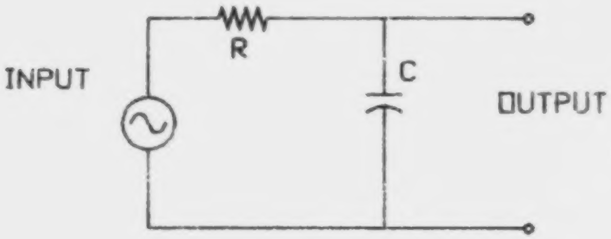


Figure B 5.1-5

"Electronic differentiation" is the process of producing an output signal that follows the instantaneous rate of change of the differentiated input signal with respect to time. In an RC differentiator, the output is developed across the resistor. The input signal is applied across both C and R. You should remember that current flow in such a circuit is controlled by the charging and discharging of the capacitor. The magnitude and the direction of this current flow is the result of the input waveform. To produce good differentiation, the time constant (RC) of the circuit must be short compared to the time period (1/f) of the input waveform. This is necessary so that the voltage developed across R truly represents the input voltage. Figure B 5.1-6 is an example of a circuit employing differentiation.

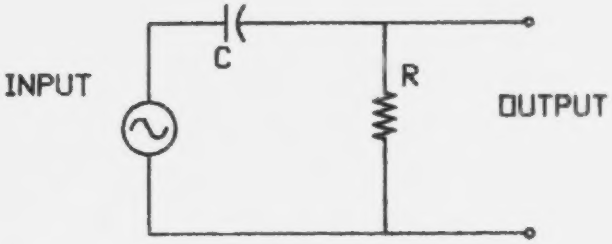


Figure B 5.1-6

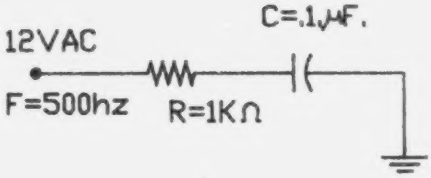
This information sheet has only skimmed the surface of RC and RL circuits. You should read as much on this subject as you can, and practice solving as many circuit problems as possible.

ACTIVITY SHEET

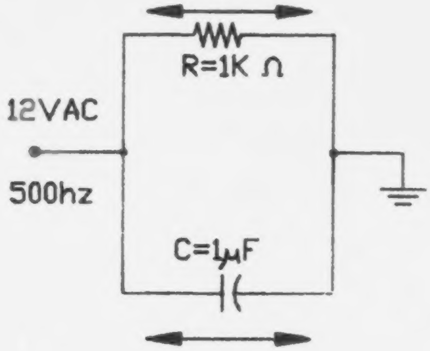
B 5.2

On separate sheet of paper complete all of the activities called for.

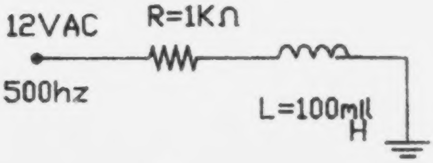
1. Find the current, impedance, and the phase angle for this circuit.


12VAC
C=.1μF.
F=500hz
R=1KΩ

2. Find the resistive current, the inductive current, the total current, and the impedance for this circuit.

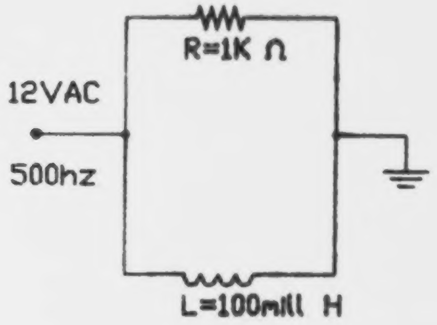

R=1K Ω
12VAC
500hz
C=1μF

3. Find the following for the circuit drawn below: voltage drop across R and L, the impedance (Z), the circuit current, and the phase difference between the inductive voltage and the resistive voltage.


12VAC
R=1KΩ
500hz
L=100mH

ACTIVITY SHEET B 5.2 CONT'D.

4. Find the following for the circuit drawn below: inductive current, resistive current, total current, impedance, and the phase difference between the two currents.


R=1K Ω
12VAC
500hz
L=100mill H

ACTIVITY SHEET ANSWER KEY

B 5.2

1. $X_C = \frac{1}{2\pi FC}$ $Z = \sqrt{X_C^2 + R^2}$ $I_T = \frac{E_T}{Z}$

$X_C = \frac{1}{6x28x500x \quad F}$ $Z = \sqrt{318^2 + 1000^2}$ $I_T = \frac{12}{1049}$

$X_C = 318\,\Omega$ $Z \approx 1049\,\Omega$ $I_T \approx 11mA$

$\text{TAN}\ \theta = \frac{-xc}{R} = \theta = \frac{-318}{1000} \approx -17.6^\circ$

2. $I_R = \frac{E}{R}$ $I_x = \frac{E}{X_C}$ $I_T = \sqrt{I_x^2 + I_R^2}$ $\theta \approx 17.6^\circ$

$I_R = \frac{12}{1000}$ $I_x = \frac{12}{318}$ $I_T = \sqrt{37.7mA^2 + 12mA^2}$

$I_R = 12mA$ $I_x = 37.7\ mA$ $I_T = 39.6mA$ $Z = \frac{12}{39.6}$

$Z = \approx 303\,\Omega$

3. $X_L = 2\pi\ FL$ $I_T = \frac{E_T}{2}$

$X_L = 6.28x500x100mA$ $I_T = \frac{12}{1048}$ $E_X = I_T x X_L$

$E_X = 3.6V$

$X_L = 314\,\Omega$

$Z = \sqrt{X_L^2 + R^2}$ $I = 11.4mA$

$Z = 1048\,\Omega$ $E_R = I_T x R$ $\text{TAN}\ \theta = \frac{E_{XL}}{E_R}$

$E_R = 11.4\ volts$ $\text{TAN}\ \theta = 17.5^\circ$

ACTIVITY SHEET ANSWER KEY B 5.2 CONT'D.

4. $I_X = \dfrac{E}{X_L}$

$I_X = \dfrac{12}{314}$

$I_X = 38.2\text{mA}$

$I_R = E/R$

$I_R = 12/100$

$I_R = 12\text{ mA}$

$I_T = \sqrt{I_x{}^2 + I_R{}^2}$

$I_T = \sqrt{38.2\text{mA}^2 + 12\text{mA}^2}$

$I_T \simeq 40\text{mA}$

$Z = \dfrac{E_T}{I_T}$

$Z \simeq 300\Omega$

$\text{TAN } \theta = \dfrac{-I_{XL}}{I_R}$

$\text{TAN } \theta \simeq -72.6^\circ$

ACTIVITY SHEET

B 5.3

On a separate sheet of paper complete all of the activities called for.

1. Draw the schematic diagram of a circuit with Xl and R in series across a 100-volt source. Calculate Z, I, IR, and the phase angle theta for these values: R = 100 ohms and Xl = 1 ohm.

2. Repeat Problem 1, using R = 1 and Xl = 100 ohms.

3. Repeat Problem 1 with R = 50 ohms and Xl = 50 ohms.

4. Can the voltage drops across the Xl and R in series be added? Why?

5. Draw the schematic diagram of a circuit with Xl and R in parallel across a 100 volt source. Calculate IR, IL, IT, Z, and theta for R = 100 ohms and Xl = 1 ohm.

6. Repeat Problem 5 for R = 1 ohm and Xl = 100 ohms.

7. Repeat Problem 5 for R = 50 ohms and Xl = 50 ohms.

8. Reviewing the data from Problems 5, 6, and 7, when would the total current (IT) be the greatest? Why?

9. How much is the impedance (Z) of a coil that allows 0.3 A current when connected across 120 volts, 60 Hz source?

10. What is the value of Xl for the coil of Problem 9 if its resistance is 5 ohms?

11. A 40-ohm R is in series with a 30-ohm X_C across a 100-V sine-wave AC source.

    (a) Draw the schematic diagram.
    (b) Calculate Z.
    (c) Calculate I.
    (d) Calculate the voltages across R and C.
    (e) What is the phase angle of the circuit?

ACTIVITY SHEET B 5.3 CONT'D.

12. A 40-ohm R and a 30-ohm X_C are in parallel across a 100 V sine-wave AC source.

    (a) Draw the schematic diagram.
    (b) Calculate each branch current.
    (c) How much is it?
    (d) Calculate Z.
    (e) What is the phase angle of the circuit?
    (f) Compare the phase of the voltage across R and X_C.

13. A 1500-ohm R is in series with a 0.01 microfarad C across 30-V source with a frequency of 8 Khz. Calculate X_C, Z_t, I, V_r, and V_C.

14. A 500-ohm R is in series with 300-ohm X_C. Find Z_t, I, and theta of Z. (phase angle of the impedance.) V_a = 120 volts AC.

15. A 500-ohm R is in parallel with a 300-ohm X_C. Find I_t, Z_t, and the phase angle of I. Compare the phase angle of I to the phase angle of Z in Problem 14. V_a = 120 volts AC.

ACTIVITY SHEET B 5.3

ANSWER SHEET

1. a) $R = 100\Omega$ $Z = \sqrt{100^2 + 1^2}$

$X_L = 1\Omega$ $Z = \sqrt{10{,}000 + 1}$

$Z = 100.005 \simeq 100\Omega$

I the same $I = \frac{V_s}{2} = \frac{100}{100} = 1$ amp

$Z = \sqrt{R^2 + X_L^2}$ $I_L = 1*1 = 1$ volt

V_L leads V_R by 90° $IR = 1*100 = 100$ volts

$\tan \theta_z = \frac{X_L}{R}$; θ increases as more X_L makes circuit inductive

$\text{TAN}\ \theta_Z = \frac{1}{100} = .573\%$

2. $R = 1\Omega$ $Z = \sqrt{R^2 + X_L^2} = Z = \sqrt{1^2 + 100^2} \simeq 100\Omega$

$X_L = 100\Omega$ $I = \frac{V_s}{Z} = \frac{100}{100} \simeq 1$ amp

$IX_L = 1*100 = 100$ volts

$IR = 1*1 = 1$ volts $\tan \theta_z = \frac{100}{1} = 89.4^\circ$

3. $R = 50\Omega$

$X_L = 50\Omega$ $Z = \sqrt{R^2 + X_L^2} = \sqrt{50^2 + 50^2} = 70.7\Omega$

$I = \frac{V_s}{Z} = \frac{100}{70.7\Omega} \simeq 1.414$ amps

$IX_L = 1.414*50 = 70.72$ volts

$IR = 1.414*50 = 70.72$ volts

$\text{Tan}\ \theta_2 = \frac{50}{50} = 1 = 45^\circ$

ACTIVITY SHEET B 5.3 CONT'D.

ANSWER SHEET

4. From this you can see that the 1st circuit is almost purely resistive. The second circuit is just the opposite, and would be considered almost totally inductive. The third circuit has equal values of resistance and inductance which yield a 45 degree impedance vector. The voltage drops are not in phase in AC circuit which is not purely resistive. They would have to be added "vectorally." $V_s = IR^2 + IX_L^2$
$V_a = 70.7^2 + 70.7^2 = 99.985 \sim 100$ volts.

5. V_A the same across X_L & R

$$I_T = \sqrt{I_R^2 + I_L^2}$$

$$Z = \frac{V_A}{I_T} \quad \text{TAN } \theta_I = \frac{-I_L}{I_R}$$

I_L lags I_R by 90°

$$R = 100\Omega \quad I_R = \frac{V_A}{R} = \frac{100}{100} = 1 \text{ amp} \quad I_L = \frac{V_A}{X_L} = \frac{100}{1} = 100\text{A}$$

$X_L = 1\Omega$

$$I_t = \sqrt{I_R^2 + I_L^2} = \sqrt{1^2 + 100^2} \simeq 100 \text{ AMPS}$$

$$Z = \frac{100}{100} \simeq 1 \text{ Ohm} \quad \text{TAN } \theta_I = \frac{-100}{1} = -89.43^\circ$$

6. $R = 1\,\Omega$ $\quad I_L = 1\text{A}$

$X_L = 100\,\Omega$ $\quad I_R = 100\text{A}$ $\quad I_t = 100\text{A}$

Z still 1 ohm $\quad \theta \simeq 0.57^\circ$

7. $$R = 50\Omega \quad I_R = \frac{V_A}{R} = \frac{100}{50} = 2\text{amp}$$

X_L 50Ω

$$I_L = \frac{V_A}{X_L} = \frac{100}{50} \; 2 \text{ amp}$$

$$I_t = \sqrt{I_R^2 + I_L^2} = \sqrt{2^2 + 2^2} = 2.828 \text{ amps}$$

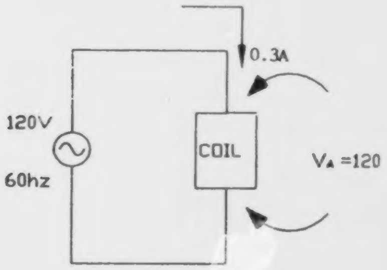
$$Z = \frac{V_A}{2.828} = 35.35\,\Omega \qquad \text{TAN } \theta_I = \frac{-2}{2} = 1 = -45^\circ$$

ACTIVITY SHEET B 5.3 CONT'D.

ANSWER SHEET

8. The greatest current in a parallel RL circuit is achieved when the branch currents, IR and IL, are equal. This occurs because the impedance of the circuits is the least amount at this point.

9.

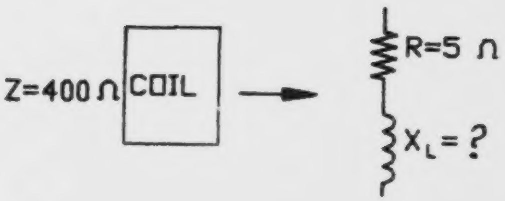

0.3A
120V
60hz
COIL
V_A =120

$$Z = \frac{V_A}{I}$$

$$Z = \frac{120}{0.3A}$$

$$Z = 400\Omega$$

10.


Z=400 Ω
COIL
R=5 Ω
X_L = ?

$$X_L{}^2 = Z^2 - R^2$$

$$X_L{}^2 = 400^2 - 5^2$$

$$X_L{}^2 = 160 \text{ X } 10^{+3} - 25$$

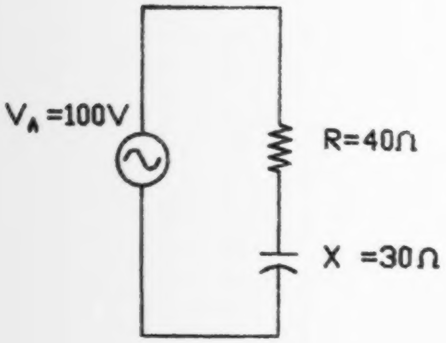
$$X_L = \sqrt{160{,}000 - 25}$$

$$X_L = 399.96\Omega$$

ACTIVITY SHEET B 5.3 CONT'D.

ANSWER SHEET

11.



$Z = R^2 + X_C^2$

$Z = 40^2 + 30^2$

$Z = 50$

$I = \dfrac{V_A}{Z}$

I is the same

$I = \dfrac{100}{50}$

$V_R = I*R$

$I = 2$ A

$V_R = 2*40 = \underline{80\ V}$

$V_C = I*X_C$

$V_C = 2*30 = \underline{60V}$

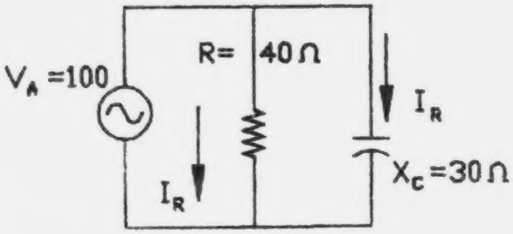
$\text{TAN } \Theta_Z = \dfrac{-X_C}{R}$

$\text{TAN } \Theta_Z = \dfrac{-30}{40} = -36.87^\circ$

ACTIVITY SHEET B 5.3 CONT'D.

ANSWER SHEET

12.



$$I_R = \frac{V_A}{R} \qquad I_{XC} = \frac{V_A}{X_C} \qquad I_t = I_R{}^2 + I_{XC}{}^2$$

$$I_R = \frac{100}{40} \qquad I_{XC} = \frac{100}{30} \qquad I_t = 2.5^2 + 3.3^2$$

$$I_R = 2.5\ \text{A} \qquad I_{XC} = 3.3\ \text{A} \qquad I_t = \underline{4.17\ \text{A}}$$

$$Z = \frac{V_A}{I_t} \qquad \text{Tan } \theta_I = \frac{I_{XC}}{I_R} = \frac{3.3}{2.5} = \underline{53.13^\circ}$$

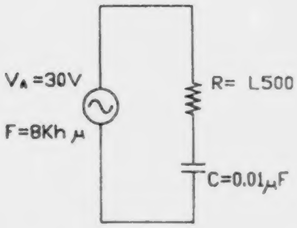
$$Z = \frac{100}{4.17\ \text{A}}$$

$\underline{Z = 24}$ Voltages across X_C and R are in phase.

ACTIVITY SHEET B 5.3 CONT'D.

ANSWER SHEET

13.



VA =30V
F=8Kh μ
R= L500
C=0.01μF

$X_C = \frac{1}{2 \quad FC}$ $\qquad Z_t = R^2 + X_C{}^2$

$X_C = \frac{1}{6.28*8Khz*0.01 \ F}$ $\qquad Z_t = 1500^2 + 1990^2$

$X_C = 1990$ $\qquad Z_t = 2492$

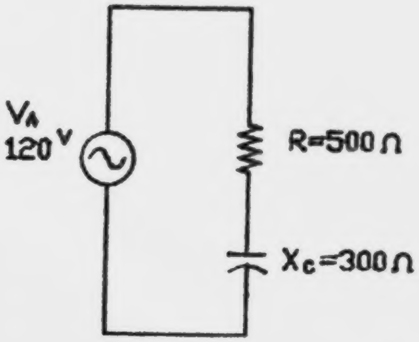
$\theta_2 = \frac{-X_C}{R} = \frac{-1990}{1500} = -52.9^0$ $\qquad I = \frac{V_A}{Z} = \frac{30}{2492} \ I = 12mA$

$V_R = I*R = 12mA * 1500 = 18.06$ volts

$V_C = I*X_C = 12mA*1990$

$V_C = 23.96$ volts

14.



VA
120V
R=500Ω
Xc=300Ω

$Z = R^2 + X_C{}^2$ $\qquad I = \frac{V_A}{Z}$ $\qquad TAN\ \theta Z = \frac{-X_C}{R} = \frac{-300}{500} \ -31^o$

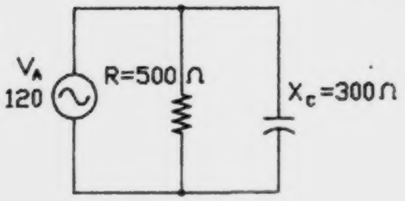
$Z = 500^2 + 300^2$ $\qquad I = \frac{120}{583.1}$

$Z = 583.1$ $\qquad I = 206mA$

ACTIVITY SHEET B 5.3 CONT'D.

ANSWER SHEET

15.



$I_R = \frac{120}{500}$ $\qquad I_t = I_R{}^2 + X_{XC}{}^2$ $\qquad Z_t = \frac{V_A}{I_t}$

$I_R = .24$ $\qquad I_t = .24^2 + .4^2$ $\qquad Z = \frac{120}{.466\text{ A}}$

$I_{XC} = \frac{120}{300}$ $\quad I_{XC} = .4$ $\qquad I_t = .466\text{A}$ $\qquad Z = 257.3$

$\text{TAN } \theta_I = \frac{I_{xc}}{I_R} = \frac{.4}{.24} = 59^\circ$ => the complement tan θ_z -31°

PROGRAM: ELECTRONICS

TASK: RC AND RL CIRCUITS

TASK # B 5.4

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

OBJECTIVE:

Given access to all necessary tools and equipment, measure and calculate RC and RL circuit characteristics including integration and differentiation.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 45 minutes and must score at least 17 out of 21 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 45 minutes and must score 17 out of 21 points or 80%, and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

RC AND RL CIRCUITS

B 5.4

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the circuit wired according to the schematic?	Y N
*2.	Does the circuit function properly?	Y N
*3.	Was necessary data recorded?	Y N
4.	Was the correct equipment used?	Y N
5.	Was the equipment used properly?	Y N
*6.	Were safety precautions followed?	Y N
*7.	Was equipment returned to proper storage area?	Y N

TOTAL POINTS POSSIBLE 21

POINTS NEEDED FOR MASTERY 17

SCORE ______

RC AND RL CIRCUITS

EXAM B 5.5

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on RC and RL circuits. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Shade in the letter associated with that choice (A or B) in the numbered blank space on the ANSWER SHEET. Use a #2 pencil to mark your answers. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, or 80%.

RC AND RL CIRCUITS

EXAM B 5.5

1. Differentiation is the process of producing an output signal that follows the instantaneous rate of a differentiated input signal.

   A. True
   B. False

2. To produce good differentiation, the time constant of the circuit must be long compared to the period of the input signal.

   A. True
   B. False

3. Integration is the process of producing an output signal that represents the sum of all the incremental changes in the input signal.

   A. True
   B. False

4. The time constant for an integrator should be long compared to the time period of the input signal.

   A. True
   B. False

5. In a series RC circuit the capacitive current leads the resistive current.

   A. True
   B. False

6. In a series RC circuit with a capacitive reactance of 318 ohms and a resistance of 1000 ohms, the phase angle between the voltages will be ________________.

   A. 72 degrees.
   B. -17.6 degrees.
   C. 17.6 degrees.
   D. -72 degrees.

7. In a parallel RC circuit the inductive current will lead or lag the resistive current?

   A. Lead
   B. Lag

8. In a series RL circuit the inductive voltage will lead or lag the resistive voltage?

   A. Lead
   B. Lag

9. In a parallel RL circuit the inductive current will lead or lag the resistive current?

   A. Lead
   B. Lag

10. The impedance of a parallel RL circuit with a total current of 40 milliamps and a total voltage of 12 volts AC is __________.

    A. 600 ohms
    B. 300 ohms
    C. 500 ohms
    D. 250 ohms

EXAM KEY B 5.5

1. A
2. B
3. A
4. A
5. B
6. B
7. A
8. A
9. B
10. B

ELECTRONICS

ANALYZING AC CIRCUITS

B 6: RLC CIRCUITS

TASK:	Using schematics analyze, construct and troubleshoot RLC circuits.
PURPOSE:	With the use of resistors, inductors and capacitors (RLC), tuned circuits can be constructed to determine oscillator frequencies and amplified frequencies, retain wanted frequencies, and eliminate interference and noise. Without these circuits, many phases of electronics could not exist.
OBJECTIVE:	Given the necessary resources on the construction and operation of various RLC circuits, you will analyze, construct, and troubleshoot RLC circuits. You must score at least 80% on a written exam and laboratory performance.

ESTIMATED CLASS TIME: 10 HOURS

RLC CIRCUITS

LEARNING STEPS

B 6

READ: Information Sheet B 6.1, "Series RLC Circuits."

READ: Information on series RLC circuits from the following resource list.

COMPLETE: Activity Sheet B 6.2, "Series RLC Circuits."

READ: Information Sheet B 6.3, "Parallel RLC Circuits."

READ: Information on parallel RLC circuits from one of the following on the resource list.

COMPLETE: Activity Sheet B 6.4, "Parallel RLC Circuits."

READ: Information Sheet B 6.5, "Complex Numbers and the j-Operator."

COMPLETE: Activity Sheet B 6.6.

COMPLETE: Activity Sheet B 6.7 "RLC Problems."

COMPLETE: Performance Checklist B 6.8.

COMPLETE: Exam B 6.9.

RECOMMENDED EQUIPMENT

VOM OR DVM
Dual-trace oscilloscope
Variable DC power supply
Variable AC power supply

RLC CIRCUITS

RESOURCES

B 6

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1984). 5th ed.
2. Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). 5th ed.
3. Badrkhan and Lark, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984).
4. Fowler, ELECTRICITY PRINCIPLES AND APPLICATION (McGraw-Hill, 1984). 2nd ed.
5. AC ELECTRONICS (Heath Company, 1982). Nineteenth Printing.

INFORMATION SHEET

B 6.1

SERIES RLC CIRCUITS

In series RLC circuits, the resistive and reactive effects must be combined by "phasors." From previous studies you should understand capacitive and inductive reactance and the formulas to determine these effects. For series circuits, first you add all the series resistances to one total R. Also combine the series reactances, adding the same kind but subtracting opposites.

Example: An inductive reactance of 100 ohms in series with a capacitive reactance of 50 ohms would total to 50 ohms of inductive reactance. Once this has been done you have one "net reactance," indicated by X. This reactance may be capacitive or inductive, depending which kind was larger. Then the total R and net X can be added by phasors to find the total ohms of opposition for the entire series circuit.

After total R and the net reactance are found, they can be combined by the formula:

$$Z = \sqrt{R^2 + X^2}$$

$$\text{If } X_L > X_C \text{ then } Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$\text{If } X_C > X_L \text{ then } Z = \sqrt{R^2 + (X_C - X_L)^2}$$

Referring to Figure B 6.1-1, the circuit has an inductive reactance of 7 ohms, a capacitive reactance of 10 ohms, with a resistive component of 4 ohms.

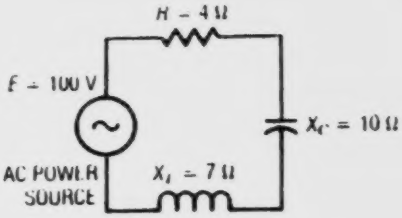


Figure B 6.1-1

Using the series impedance formula, $Z = \sqrt{R^2 + X^2}$

$Z = \sqrt{4^2 + 3^2}$

$Z = \sqrt{16 + 9}$

$Z = \sqrt{25}$

Z = 5 ohms

INFORMATION SHEET B 6.1 CONT'D.

If a voltage is applied to a series RLC circuit, the current can be determined by the formula:

$$I = \frac{E}{Z}$$

Using this formula, the current in Figure B 6.1-1 would be: $\frac{100}{5}$ = 20 amps.

Ohms law can also be used to determine the voltage drop across each component in the circuit.

E_R = IR = 20 x 4 = 80 V.
E_C = IX = 20 x 10 = 200 V.
E_L = IX = 20 x 7 = 140 V.

The power factor in an AC circuit is the ratio of real power to apparent power. To find the power factor for a series AC circuit, divide its resistance (representing real power) by its impedance (representing apparent power). From previous studies you learned that reactances do not use power, they store it then return it.

The formula for power factor is: $PF = \frac{R}{Z}$

The power factor in Figure B 6.1-1 is determined as follows:

$$PF = \frac{4}{5} = 0.80$$

Once the power factor has been determined, phase angle can be calculated, using the following formula:
θ = Arc tan 0.80 = 38.66°
Since the inductive and capacitive voltages ae 180° out of
$E_C - E_L$ = 200 - 140 = 60 V.
To reinforce your knowledge of vectors, a study of Figure B 6.1-2 should be made at this time.

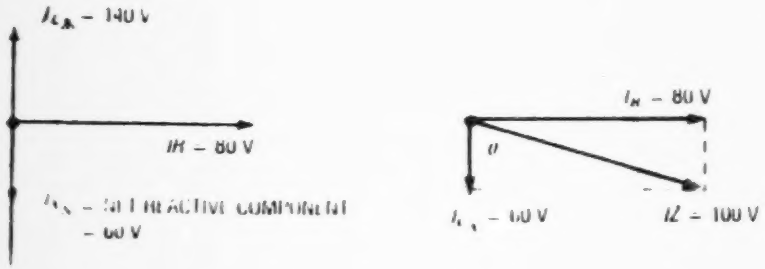


Figure B 6.1-2

ACTIVITY SHEET

B 6.2

1. A circuit has a resistance of 60 Ohms, a capacitive reactance of 125 ohms, and an inductive reactance of 100 ohms. What is the impedance of the circuit?

2. What is the current in the above circuit if the applied voltage is 260 volts?

3. Determine the phase angle in the above circuit.

4. Determine the voltage drop across each component in the above circuit.

5. Draw the impedance vector for the above circuit.

ACTIVITY SHEET B 6.2

ANSWER KEY

1. 65 ohms

2. 4 amps

3. 22.6

4. E_R = 240 volts, E_C = 500 volts, E_L = 400 volts

5. Figure B 7.2-1

INFORMATION SHEET

B 6.3

PARALLEL RLC CIRCUITS

To determine the impedance of an AC parallel circuit containing RLC components, you can use Ohm's law just as it is used for the series AC circuits. The formula is: $Z = \frac{E}{I}$

Notice that this formula requires the total current. Two methods can be used to determine the total current. The easier of the two is the formula:

$$I_T = \sqrt{I_R^2 + I_x^2}.$$

When both capacitive and inductive reactance are involved, use the formula:

$$I_T = \sqrt{I_R^2 + (I_{XC} - I_{XL})^2}$$

Example: Using Figure B 6.3-1, the branch currents are

$I_R = .5$ amperes, $I_L = 1$ ampere, $I_C = .4$ amperes.

These are represented by the vector diagram in Figure B 6.3-1.

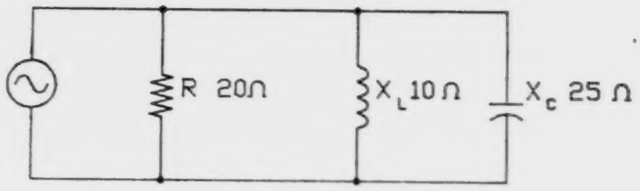


Figure B 6.3-1

The total current can now be shown in Figure B 6.3-2. This shows that $I_R = .5$ amps and $I_x = .6$ amps. Total current can now be calculated, using the formula:

$I_T = \sqrt{I_R^2 + I_x^2.1} = \sqrt{.5^2 + .6^2}$, $I_T = \sqrt{.61}$, $I_T = .78$ amps.

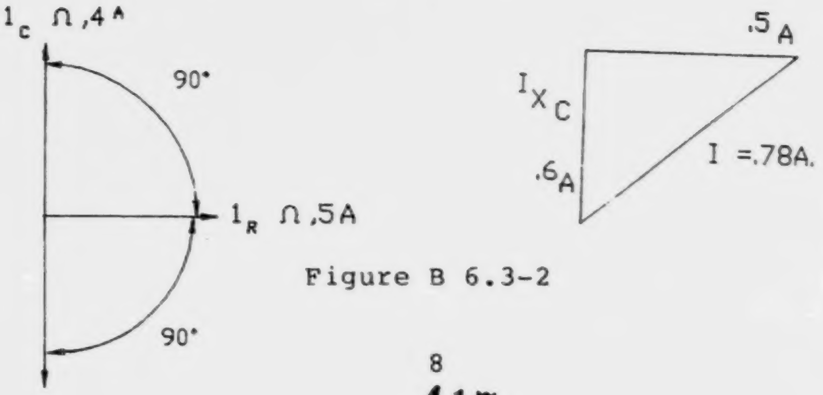


Figure B 6.3-2

Once we know the total current, we can compute the other values. For example: $Z = \frac{E}{I} = \frac{10}{.78} = 12.8$ ohms.

The phase angle can be found by the formula;

$$\text{Tan } \theta = \frac{I_X}{I_R} = \frac{.6}{.5} = 1.2$$

Using a tangent table, this corresponds to an angle of about 50 degrees. Since the reactive current was inductive, the current lags the voltage by about 50 degrees.

The other method of solving parallel impedances is to use the reciprocals of the resistance and the reactance. The "reciprocal of the resistance" is the "conductance" (G). The "reciprocal of the reactance" is the "susceptance" (B). The "reciprocal of the impedance" is the "admittance" (Y). All of these are measured in "siemens."

The total susceptance is determined by the formula:

$$B_T = B_L - B_C$$

Once you have determined the total susceptance, the "net admittance" is determined by the formula:

$$Y = G^2 + B^2.$$

To determine the impedance, the reciprocal of admittance is used:

$$Z = \frac{I}{Y}$$

ACTIVITY SHEET

B 6.4

1. A $Y = \sqrt{G^2 + B^2}$.

   To determine the impedance, the reciprocal of admittance is used:

   $$Z = \frac{I}{Y}$$

   Parallel RLC Circuit has a resistance of 5 ohms, capacitive reactance of 3 ohms and inductive reactance of 15 ohms. The applied voltage is 60 volts.

   Calculate the individual currents.

   A. I_R =
   B. I_C =
   C. I_L =
   D. I_T =

2. Determine the phase angle of the above circuit.

3. What is the impedance of the above circuit?

4. From the above circuit, using your calculators, find the true power, apparent power, and power factor.

ACTIVITY SHEET B 6.4

ANSWER KEY

1. A. 12A
   B. 20A
   C. 4A
   D. 20A
2. 53
3. 3 ohms
4. A. 720 watts
   B. 1200 VA
   C. .6

INFORMATION SHEET

B 6.5

COMPLEX NUMBERS AND THE j-OPERATOR

In computations involving AC circuits, an additional variable must often by considered. This variable is the "phase angle," which plays a significant part in the performance of the circuit. The phase angle makes AC computations more complex. As more reactive components are added to the circuit, the greater the complexity of the computations can be.

To simplify the computations of these circuits, the j-operator is used. The j-operator is the imaginary component of a complex number used in mathematical formulas. Note: if you do not understand the concept of imaginary numbers, see your instructor for resources available in your school.

The j-operator is used to denote the phase angle. For an angle of 0, such as resistance, a real number is used without any j-operator. An angle of 90 degrees or +j is used for inductive reactance X. An angle of -90 degrees or -j is used for capacitive reactance. Refer to Figure B 6.5-1 for examples.

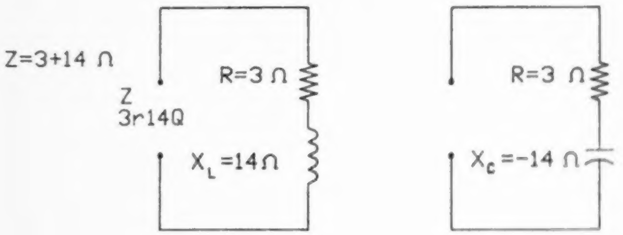


Figure 6.5-1

For reactive branch currents, the sign for j is reversed, compared with reactive ohms, because of the opposite phase angle. Refer to Figure B 6.5-2 for examples.

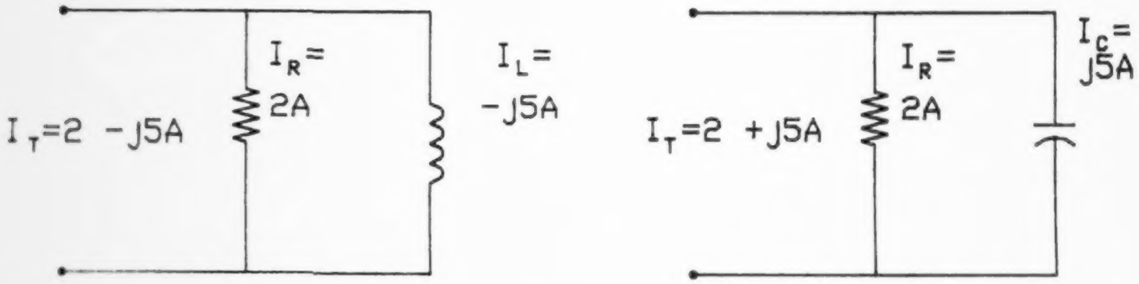


Figure 6.5-2

INFORMATION SHEET B 6.5 CONT'D.

The rectangle form of complex numbers is a convenient way to express the impedance of a series resistance and reactance. In Figure B 6.5-1a, the impedance is 3 + j4, as Z is the phasor sum of 3 ohms r in series with j4 ohms for X_L. Similarily, Z_b is 3 - j4 for a 3 ohms R in series with -j4 ohms for s R in series with 2,000 ohms X: Z = 4000 - j2000.

In general, $Z = R \pm jX$. If one term is zero, substitute 0 s R n series with 2,000 ohms X: Z = 4000 - j2000.

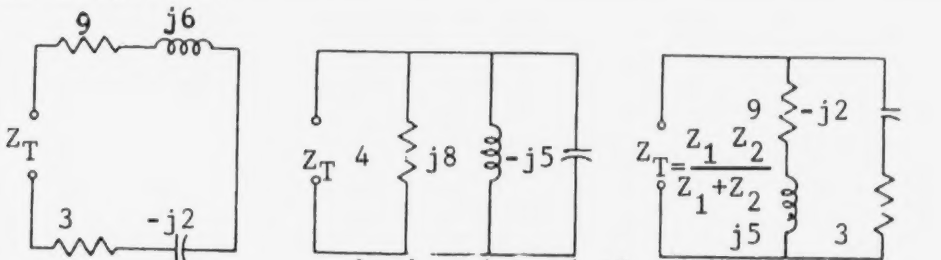
In general, $Z = R \pm jX$. If one term is zero, substitute 0 for this term. The advantage of this method is that multiple impedances written as complex numbers can then be calculated as follows:

For series Z: $Z_T = Z_1 + Z_2 + Z_3 + \ldots + \text{etc.} \ldots$

For parallel $Z = \dfrac{1}{\dfrac{1}{Z_1} + \dfrac{1}{Z_2} + \dfrac{1}{Z_3}}$ . . . .etc. .

$$\text{or } Z = \frac{Z_1 + Z_2}{Z_1 + Z_2}$$

Examples are shown in Figure B 6.5-3. For addition, subtraction, multiplication, and division of complex numbers, refer to resource materials.



$\frac{1}{2}T = \frac{1}{4} + 1/j8 + 1/-j5$

$Z_T = (9+j6)+(3-j2)$

Figure B 6.5-3

$Z_T = \dfrac{(9+j5)\times(3-j2)}{(9+j5)+(3-j2)}$

Complex numbers can be expressed in polar form. To convert any complex number to polar form:

1. Find the magnitude by phasor addition of the j term and real term.
2. Find the angle whose tangent is the j term divided by the real term.

See the following examples:

$2 + j4 = 4.47 \angle 63$ degrees $\quad 4 + j2 = 4.47 \angle 26.5$ degrees
$8 + j6 = 10 \angle 37$ degrees $\quad 8 - j6 = 10 \angle -37$ degrees
$4 + j4 = 5.66 \angle 45$ degrees $\quad 4 - j4 = 5.66 \angle -45$ degrees

The polar form is more convenient for multiplying or dividing complex numbers.

For multiplication, you multiply the magnitude and add the angles algebraically.

$24 \angle 40 \times 2 \angle 30^\circ = 48 \angle 70^\circ$
$24 \angle 40 \times (-2 \angle 30^\circ) = -48 \angle 70^\circ$
$12 \angle -20 \times 3 \angle -50^\circ = 36 \angle 70^\circ$
$12 \angle -20 \times 4 \angle 5^\circ = 48 \angle -15^\circ$

For division, you divide the magnitudes and subtract the angles algebraically:

$24 \angle 40^\circ \div 2 \angle 30^\circ = 12 \angle 10$
$12 \angle 20^\circ \div 3 \angle 50^\circ = 4 \angle -30$
$12 \angle -20^\circ \div 4 \angle 50^\circ = 3 \angle -70$

To convert from polar to rectangluar: the real term for R : $R = Z \cos \theta$. The real term for X: $X = Z \sin \theta$.

Example: To convert $5 \angle 37$: $R = Z \cos \theta = 5 \times .8 = 4$
$Z = Z \sin \theta = 5 \times .6 = 3$
Therefore: $5 \angle 37^\circ = 4 + j3$

Likewise: $5 \angle -37$: $R = Z \cos \theta = 5 \times .8 = 4$
$Z = Z \sin \theta = 5 \times (-.6) = -3$
Therefore: $5 \angle -37^\circ = 4 - j3$

ACTIVITY SHEET

B 6.6

Match the values in the column at the left with those at the right.

1. $24 + j5 + 16 + j10$
2. $24 - j5 + 16 - j10$
3. $j12 \times 4$
4. $j12 \times j4$
5. $j12 \quad j3$
6. $(4 + j2) \times (4 - j2)$
7. 1200 ohms of R + 800 of X
8. 5A of I_R + 7A of I_C
9. 90V of V_R + 60 v of V_L
10. $14 \angle 28 \times \angle 22^\circ$
11. $14 \angle 28 \quad 2 \quad \angle 22^\circ$
12. $15 \angle 42 \times 3 \quad \angle 0^\circ$
13. $6 \angle 75 \times 4 \quad \angle 30^\circ$

a. $14 \angle 50^\circ$
b. $7 \angle 6^\circ$
c. $1200 - j800$ ohms
d. $40 + j15$
e. $90 + j60$V
f. $45 \angle 42^\circ$
g. $24 \angle -45^\circ$
h. 4
i. $j48$
j. -48
k. $5 + j7$A
l. 20
m. $40 - j15$

14. Find the total Z in rectangular form for the following three series impedances.

A. $12 \angle 10^\circ$
B. $25 \angle 15^\circ$
C. $34 \angle 26^\circ$

ACTIVITY SHEET B 6.6

ANSWER SHEET

1. d
2. m
3. i
4. j
5. h
6. l
7. c
8. k
9. e
10. a
11. b
12. f
13. g
14. $Z_T = 65.36 + j23.48$

ACTIVITY SHEET

B 6.7

RLC PROBLEMS

1. Calculate the impedance of the circuit in Figure B 6.7-1, if $\omega = 2\text{x}10^6$ rad/sec. What will the impedance diagram and equivalent circuit look like? (Note: $\omega = 2\pi F$ also V_s is given in term of angular velocity)

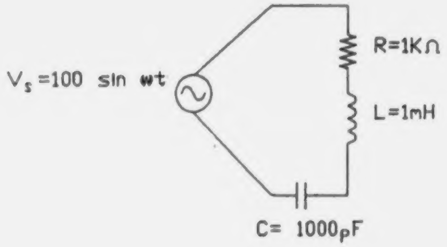

V$_s$=100 sin ωt
R=1KΩ
L=1mH
C= 1000pF

Figure B 6.7-1

2. Repeat problem number 1 with the frequency reduced by a factor of 4. ($\omega = 0.5\text{x}10^6$ rad/sec.)

3. Repeat problem number 1 again, but this time with the frequency only reduced by 2.

4. Calculate the element voltages for problem number 1 and draw the complete phasor diagram.

5. What is the total impedance of Figure number B 6.7-2?

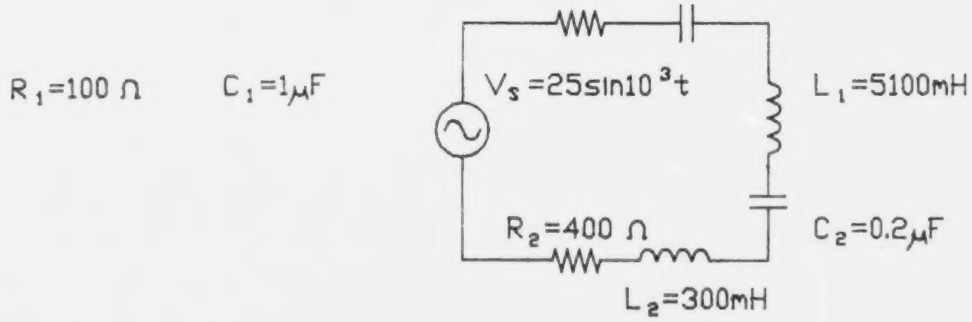

R$_1$=100 Ω
C$_1$=1μF
V$_s$ =25sin10^{3}t
L$_1$=5100mH
R$_2$=400 Ω
C$_2$=0.2μF
L$_2$=300mH

Figure B 6.7-2

6. Draw the equivalent circuit for the problem number 5.

7. Is the circuit of problem inductive of capacitive?

ACTIVITY SHEET B 6.7 CONT'D.

8. Find the total impedance of the circuit in Figure B 6.7-3.

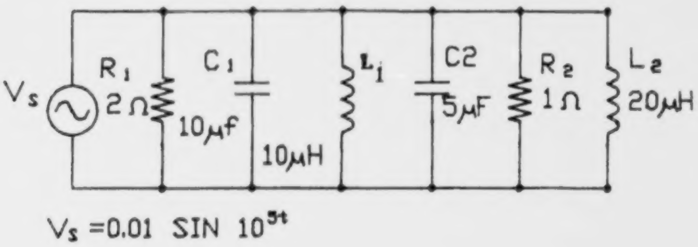

Vs
R1
2Ω
C1
10μf
L1
10μH
C2
5μF
R2
1Ω
L2
20μH
Vs =0.01 SIN 10^5t

Figure B 6.7-3

9. Calculate the admittance of the circuit in Figure B 6.7-4. ($\omega = 1 \times 10^{+4}$ rad/sec) R = 1KΩ, L = 0.2H and C = 0.1 μF.

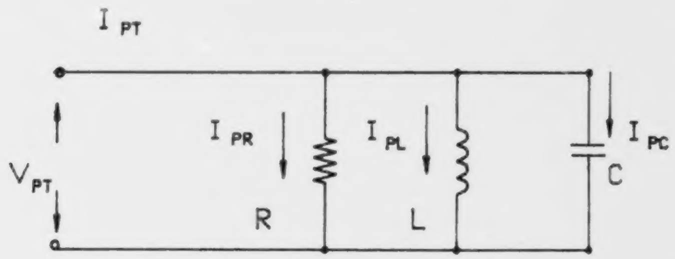

I PT
V PT
I PR
R
I PL
L
I PC
C

Figure B 6.7-4

10. Calculate the total admittance for Figure B 6.7-5 if $\omega = 1 \times 10^{+3}$. Draw the admittance diagram.

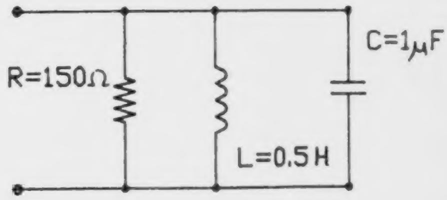

R=150Ω
L=0.5H
C=1μF

Figure B 6.7-5

ACTIVITY SHEET

B 6.7

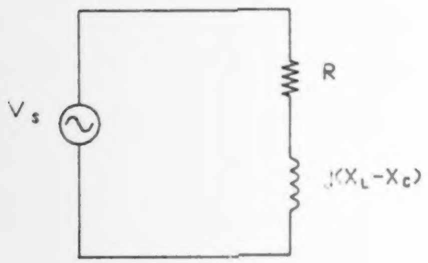
ANSWER SHEET

1. $X_L = \omega L = 2 \times 10^6 \times 1mH = 2K\Omega$

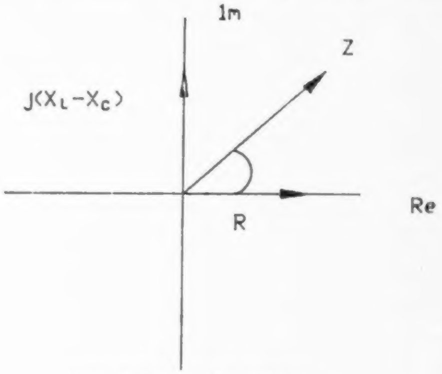
$$X_C = \frac{1}{\omega C} = \frac{1}{2x10^6 \times 1000pF} = 0.5K\Omega$$

$Z = R + j\ (X_L - X_C) = 1K\Omega + j\ (2K\Omega - 0.5K\Omega) = (1 + j\ 1.5)\ K\Omega$

This is an inductive circuit



Equivalent Circuit



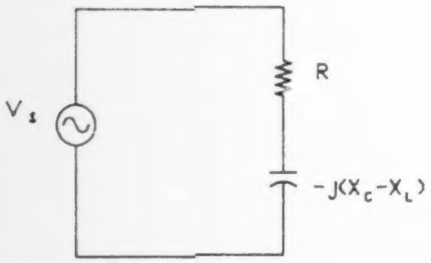
Vector Diagram

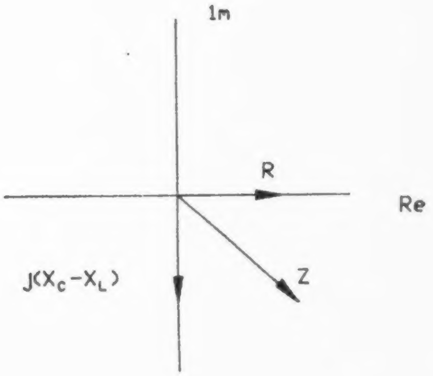
2. $X_L = \omega L = 0.5 \times 10^{+6} * 1mH = 0.5K\Omega$

$$X_C = \frac{1}{\omega C} = \frac{1}{0.5 \times 10^{+6} * 1000pF} = 2\ K\Omega$$

$Z = R + j\ (X_L - X_C) = 1K\Omega + j\ (0.5K\Omega - 2K\Omega) = (1 - j\ 1.5)\ K\Omega$

Circuit capacitive at the lower freq.





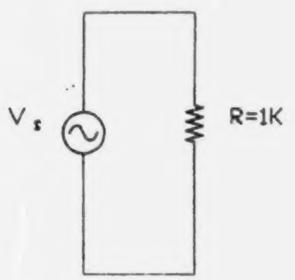
3. $\omega = 10^6$ rad/sec

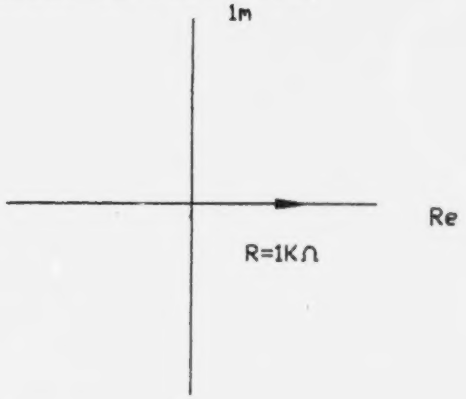
$$X_L = \omega L = 1*10^{+6} * 1mH = 1K\Omega$$

$$X_C = \frac{1}{\omega C} = \frac{1}{1*10^{+6} * 1000pF} = 1K\Omega$$

$$Z = R + j\,(X_L - X_C) = 1K\Omega + j\,(1 - 1)K\Omega) = 1K\Omega + jo = 1K\Omega$$

Reactance cancel Z = R the circuit is resistive.





4. Series RLC so $I_p = I_p = I_p \angle 0^{\circ}$

$$\text{Current} \Rightarrow I_p = \frac{V_{ps}}{Z} = \frac{100 \angle 0^{\circ}\ V}{(1 + j\,1.5)*1K\Omega} = \frac{100\angle 0^{\circ}}{1.8 \angle 56.3^{\circ}\ K\Omega}$$

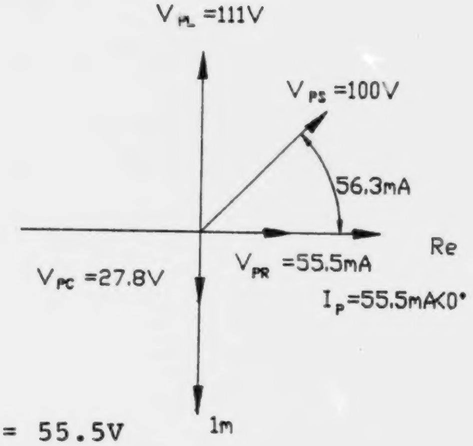
$$= 55.5 - 56.3^{\circ}mA$$

Note conversion from rec. to Polar

Since you want the current on the reference, rewrite the current of voltage source phasors as (Vps leads Ip by 56.3°). Also note this clarifies the fact that the circuit is inductive in nature.

$V_{ps} = 100 \angle 56.3^\circ \text{ V}$

$I_p = 55.5 \angle 0^\circ \text{ mA}$



$V_{PR} = I_P * R = 55.5\text{mA} * 1\text{K}\Omega = 55.5\text{V}$

$V_{pL} = j\ I_p * X_L = j\ 55.5\text{mA} * 2\text{K}\Omega = j\ 111\ \text{V}$

$V_{pc} = -j\ I_p * X_c = -j\ 55.5\text{mA} * 0.5\text{K}\Omega = -j\ 27.8\text{V}$

5. Find impedance of each element. $\omega = 1\text{x}10^{+3}t$

$Z_1 = R_1 = 100\Omega \qquad Z_2 = \dfrac{1}{\omega C} = \dfrac{1}{1\text{x}10{+}3 * 140^{-6}} = -j\ 1000\Omega$

$Z_4 = \dfrac{1}{\omega C} = \dfrac{1}{1\text{x}10^3 * 0.2\mu\text{F}} = -j\ 5000\Omega$

$Z_3 = \omega L = 1\text{x}10^{+3} * 5100\text{mH} = j\ 5100\Omega$

$Z_5 = \omega L = 1 * 10^3 * 300\text{mH} = j\ 300\Omega \qquad Z_6 = R_2 = 400\Omega$

$Z_T = Z_1 + Z_2 + Z_3 + Z_4 + Z_5 + Z_6$

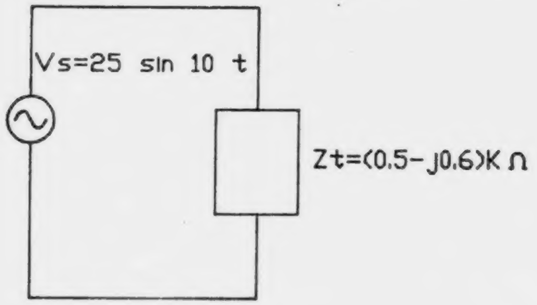
$Z_t = 100\Omega - j1000\Omega + j5100\Omega - j5000\Omega + j300\Omega + 400\Omega = 500\Omega - j\ 600\Omega$

$= (0.5 - j\ 0.6)\text{K}\Omega$

Note: You could also find total Z by combining all R's, C's and L's into total R's, C's, & L's.

ACTIVITY SHEET B 6.7 CONT'D.

6.



$Z_t = (0.5 - j\ 0.6)\,K\ \Omega$

7. Capacitive

8. Find the Z of each element:

$$Z_1 = R_1 = 2\Omega \qquad Z_2 = X_{c1} = \frac{1}{\omega C_1} = \frac{1}{1x\ 10^{+5} * 10\mu F} = 1\Omega$$

$$Z_2 = -j\ X_{c1} = -j1\Omega$$

$$Z_3 = XL1 = W*hl = 1x10^{+5}*10\mu H = 1\Omega \quad Z_3 = j\ XL_1 = j\ 1\Omega$$

$$Z_4 = C2 = X_{C2} = \frac{1}{\omega C_2} = \frac{1}{1x10^{+5}*5\mu F} = 2\Omega = -j2$$

$$Z_5 = R_2 = 1\Omega$$

$$Z_6 = L_2 = XL_2 = \omega L_2 = 1x10^{+5}*20\mu H = 2\Omega = j2$$

$$Z_t = \frac{1}{\frac{1}{Z_1} + \frac{1}{Z_2} + \frac{1}{Z_3} + \frac{1}{Z_4} + \frac{1}{Z_5} + \frac{1}{Z_6}} = \frac{1}{\frac{1}{2} + \frac{1}{-j_1} + \frac{1}{j1} + \frac{1}{-j2} + \frac{1}{1} + \frac{1}{j2}}$$

Multiply by j2

$$Z_t = \frac{j2}{j - 2 + 2 - 1 + j2 + 1} = \frac{j2}{j3} = \frac{2}{3} + j0 = \frac{2}{3}\ \Omega$$

$$Z = 2/3\,\Omega$$

ACTIVITY SHEET B 6.7 CONT'D.

9. $G = \frac{1}{R} = \frac{1}{1K\Omega} = 1mS$ $\qquad B_C = \omega C = 10^4 * 0.1\mu F = 1mS$

$$B_L = \frac{1}{\omega L} = \frac{1}{10^4 * 0.2\mu H} = 0.5mS$$

$Y = G + j(B_C - B_L) = 1mS + j\ (1-0.5)mS = (1tj0.5)mS$

Rect. to Polar:

$$y = \sqrt{G^2 + B^2} = \sqrt{(10^{-3})^2 + (0.5 \times 10^{-3})^2} = \sqrt{1.25 \times 10^{-3}} =$$

$$1.12 \times 10^{-3}$$

$$\phi = \tan^{-1} \frac{(B_C - B_L)}{G} = \tan^{-1} \frac{0.5mS}{1mS} = \tan^{-1} 0.5 = 26.6^o$$

10. $G = \frac{1}{R} = \frac{1}{150} = 6.67mS$ $\qquad B_c = \omega C = 1x10^{+3}x1\mu F = 1mS$

$$B_L = \frac{1}{\omega L} = \frac{1}{1x10^{+3}x0.5H} = 2mS$$

Polar Form:

$$Y = \sqrt{G^2 + (B_C - B_L)^2} = \sqrt{6.67X\ 10^{-3})^2 + 10^{-3}\ ZX10^{-3})^2}$$

$$= \sqrt{(44.5 + 1)10^{-6}} = 6.75mS$$

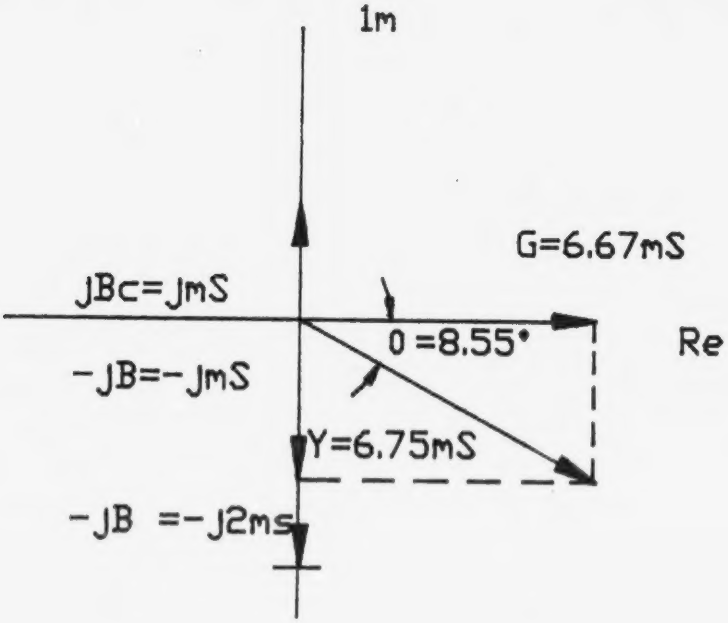
$$\phi = \tan^{-1} \frac{(B_C - B_L)}{G} = \tan^{-1} \frac{(1-2)mS}{6.67mS} = \tan^{-1} \frac{-1}{6.67} = -8.55^o$$

Polar to Rec. $B = Y \sin\phi = 6.7mS \times \text{Sin}\ (-8.55^o) = -1mS$

$G = Y \cos\phi = 6.75mS * \text{Cos}\ (-8.55^o) = 6.67mS$

ACTIVITY SHEET B 6.7 CONT'D.

Admittance diagram:


Im
G=6.67mS
JBc=JmS
0 =8.55°
Re
-JB=-JmS
Y=6.75mS
-JB =-J2ms

PROGRAM: ELECTRONICS

TASK: RLC CIRCUITS

TASK # B 6.8

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE __________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT __________

TERMINAL PERFORMANCE OBJECTIVE:

Analyze, construct and troubleshoot RLC circuits.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and you must score at least 7 out of 8 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 7 out of 8 points, or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

RLC CIRCUITS

PERFORMANCE/PRODUCT CHECKLIST

B 6.8

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Does circuit function correctly?	Y N
*2.	Was circuit wired according to schematic?	Y N
3.	Are connections correct?	Y N
4.	Was necessary data recorded?	Y N
5.	Was correct equipment used?	Y N
*6.	Was equipment used properly?	Y N
*7.	Were safety precautions followed?	Y N
8.	Was equipment returned to proper storage?	Y N
	TOTAL POINTS POSSIBLE	______
	POINTS NEEDED FOR MASTERY	______
	SCORE	______

RLC CIRCUITS

EXAM B 6.9

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on RLC circuits. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your ANSWER SHEET. DO NOT WRITE ON THIS TEST!!!! To master this exam you must answer 16 out of 20 items correctly, 80%.

EXAM

B 6.9

For a series RLC circuit with an R of 60 ohms, capacitive reactance of 10 ohms and an inductive reactance of 90 ohms, apply 300 and volts calculate the following:

1. Impedance ____________ ohms.

   A. 111
   B. 160
   C. 140
   D. 100

2. Total current __________ amps.

   A. 3
   B. 2.85
   C. 2.13
   D. 2.6

3. E_L _____________ volts.

   A. 234
   B. 270
   C. 186
   D. 240

4. E_C ____________ volts.

   A. 28.5
   B. 26
   C. 30
   D. 21.3

5. E_R ____________ volts.

   A. 170
   B. 127
   C. 156
   D. 180

6. True power _____________ watts.

   A. 900
   B. 720
   C. 540
   D. 600

7. Apparent power __________ watts.

   A. 1200
   B. 900
   C. 720
   D. 600

8. Power factor is ____________.

   A. .6
   B. .85
   C. .72
   D. 600

In a parallel RLC circuit within an R of 12 ohms, an inductive reactance of 9 ohms and a capacitive reactance of 12 ohms and an applied voltage of 360 volts, calculate the following.

9. I_r is ________________ amps.

   A. 40
   B. 24
   C. 34
   D. 30

10. I_C is _______________ amps.

   A. 24
   B. 34
   C. 40
   D. 30

11. I_L is _______________ amps.

   A. 30
   B. 24
   C. 40
   D. 34

12. I_T is ______________ amps.

   A. 30
   B. 40
   C. 24
   D. 34

EXAM B 6.9 CONT'D.

13. Convert $14.14 \angle 45^{\circ}$ to rectangular form.

A. 14.14 + j14.14
B. 10 + j10
C. 10 - j10
D. 20 + j10

14. Find I_T in rectangular form for I_1 of 0 + j2A and I_2 of 4 + j3A.

A. 4 + j5
B. 4 - j1
C. 4 - j5
D. 0 + j5

The following components are in series; L = 100 μH, C = 20 pF, R = 2000 ohms. The frequency is 2MHz. The applied voltage is 80 volts. Calculate the following;

15. Inductive reactance is ______________ ohms.

A. 4000
B. 1260
C. 126
D. 400

16. Capacitive reactance is _____________ ohms.

A. 400
B. 126
C. 4000
D. 1260

17. Impedance is ______________ ohms.

A. 3390
B. 339
C. 5260
D. 2740

18. Total current is ______________.

A. 2A $\angle 37.1^{\circ}$
B. 23.6 mA $\angle 53.9^{\circ}$
C. 23.6 mA $\angle -53.9^{\circ}$
D. 2 mA $\angle -37.1^{\circ}$

19. $45 \angle 24^\circ + 10 \angle 10^\circ$ equals ___________.

A. $35 \angle 14^\circ$
B. $45 \angle -14^\circ$
C. $4.5 \angle 14^\circ$
D. $35 \angle -14^\circ$

20. $45 \angle 24^\circ \times 10 \angle 54^\circ$ equals ____________.

A. $450 \angle 78^\circ$
B. $450 \angle 30^\circ$
C. $450 \angle -30^\circ$
D. $4.5 \angle 30^\circ$

EXAM B 6.9

1. C
2. A
3. B
4. C
5. D
6. C
7. B
8. A
9. D
10. D
11. C
12. D
13. B
14. A
15. B
16. C
17. A
18. B
19. C
20. A

ELECTRONICS

ANALYZING AC CIRCUITS

B 7: SERIES AND PARALLEL RESONANT CIRCUITS

TASK: Using schematics analyze, construct, and troubleshoot series and parallel resonant circuits.

PURPOSE: Inductive reactance increases as the frequency is increased, but capacitive reactance decreases with higher frequencies. This means any LC combination will have a frequency where X_L equals X_C. This is called resonance and the AC circuit is called a resonant circuit. The most common application of resonance is called tuning. All examples of tuning in radio and television are applications of resonance. You must have a thorough understanding of the resonant circuit.

OBJECTIVE: Given the necessary information and resources, you will use schematics to analyze and apply the principles of resonance to both series and parallel circuits. To master this task you must score at least 80% on the written exam and laboratory performance.

ESTIMATED CLASS TIME: 10 HOURS

LEARNING STEPS

B 7

READ: Information Sheet B 7.1, "Series Resonant Circuits."

READ: Information on series resonant circuit in one or more of the following resources.

COMPLETE: Activity Sheet B 7.2, "Series Resonant Circuits."

READ: Information Sheet B 7.3, "Parallel Resonant Circuits."

READ: Information on parallel resonant circuits in one or more of the following resources.

COMPLETE: Activity Sheet B 7.4, "Parallel Resonant Circuits."

COMPLETE: Activity Sheet B 7.5, "Resonant Problems."

COMPLETE: Laboratory Performance Checklist B 7.6.

COMPLETE: Exam B 7.7.

RECOMMENDED EQUIPMENT

Dual-trace oscilloscope

VOM or DVM

AF-RF generator

Various resistors, inductors and capacitors

Variable DC power supply

Variable AC power supply

SERIES AND PARALLEL RESONANT CIRCUITS

RESOURCES

B 7

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1984). 5th ed.
2 Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). 5th ed.
3. Badrkhan and Lark, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984).
4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS (McGraw-Hill, 1984). 2nd ed.
5. AC ELECTRONICS (Heath Company, 1982). Nineteenth Printing.

INFORMATION SHEET

B 7.1

SERIES RESONANT CIRCUITS

The reactance of capacitors and inductors varies with frequency. However, as frequency increases, inductive reactance goes up and capacitive reactance goes down; thus, at one frequency they will be the same. This is called "resonance." If the components are connected in series, it is known as "series resonance." This type of circuit is shown in Figure B 7.1-1.

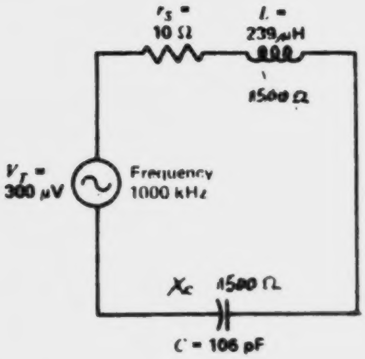


Figure B 7.1-1

In a series AC circuit, the inductive reactance leads by 90°, compared to the zero reference angle of the resistance. While the capacitance reactance lags by 90°, the X_L and X_C are 180° out of phase. Being 180° out of phase causes the two reactances to cancel each other. This results in a net reactance of zero ohms, with the only reactance in the circuit being the resistance of the coil (R_S). Figure B 7.1-2 shows the properties of the RLC series resonant circuit.

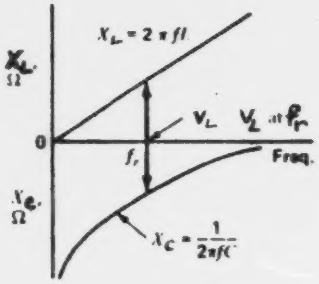


Figure B 7.1-2

The main characteristic of a series resonant circuit is "resonant rise" of current at the resonant frequency. Figure B 7.1-3 shows the response curve of a circuit resonant at 1000 KHz.

The formula for determining the resonant frequency (f_r) is:

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

L is the inductance in Henrys, C is the capacitance in Farads. Referring to Figure B 7.1-3:

1. Below resonance X_L is small, but X_C is large and limits the current flow.
2. Above resonance X_C is small, but X_L is large and limits the current flow.
3. At resonance, X_L and X_C cancel allowing maximum current flow.

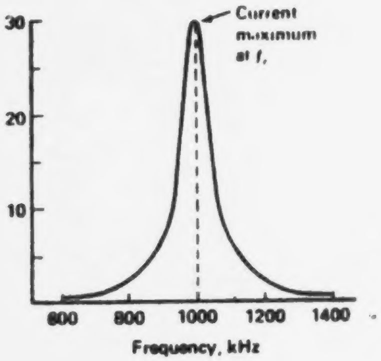


Figure B 7.1-3

From previous studies, it has been shown that when high current flows in a circuit, high voltage will be produced across a reactance. Figure B 7.1-4 shows the voltages produced in a series resonant circuit. The voltages across the combination will be zero, but across each component a high voltage does appear; in order to use the resonant effect, the output must be connected across either L or C.

In summary, the main characteristics of the series resonant circuit are:

A. At resonance the maximum current flows.

B. The phase angle of the current is in phase with the input current ($\theta = 0$).

C. The voltage is maximum across either L or C.

D. The impedance is minimum, and equals only the low coil resistance.

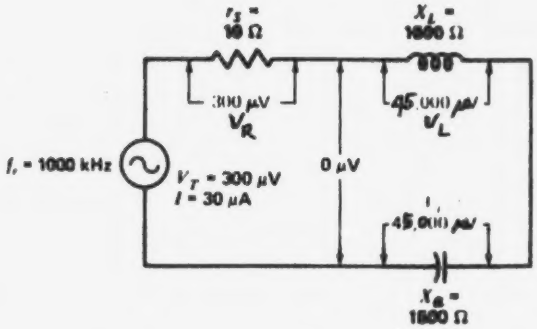

r_s =
10 Ω
300 μV
V_R
X_L =
1800 Ω
45,000 μV
V_L
f_r = 1000 kHz
V_T = 300 μV
I = 30 μA
0 μV
45,000 μV
X_C =
1800 Ω

Figure B 7.1-4

ACTIVITY SHEET

B 7.2

1. In a series RLC circuit, resonance occurs when

   A. X_L is ten times X_C
   B. X_C is ten times X_L
   C. $X_L = X_C$
   D. the phase angle is 90^o.

2. If L is increased in a series resonant circuit, the resonant frequency will

   A. increase
   B. decrease
   C. remain the same
   D. depends on R .

3. The resonant frequency for an L of 8 H, and C of 20 μF will be

   A. 60 Hz
   B. 1000 Hz
   C. 12.6 Hz
   D. 12.6 KHz.

4. Find f_r for L of 320 μh and C of 30 pF.

   A. 1000 KHz
   B. 1.624 MHz
   C. 16.24 MHz
   D. 162.4 MHz.

5. At resonance, X_L and X_C are maximum.

   A. True
   B. False

6. At resonance, X_L and X_C are equal.

   A. True
   B. False

7. At resonance I_L is minimum.

   A. True
   B. False

ACTIVITY SHEET B 7.2

ANSWER SHEET

1. C
2. B
3. C
4. D
5. B
6. A
7. B

INFORMATION SHEET

B 7.3

PARALLEL RESONANT CIRCUITS

When capacitors, inductors, and resistors are connected in parallel in virtually any combination, these circuits have the same properties as series resonant circuits. Most important is that resonance exists when $X_L = X_C$.

When an inductor and capacitor are in parallel, resonant frequency of the currents is equal and 180° out of phase. The currents then cancel each other and as a result, minimum current flows in the circuit. Minimum current flow results in a high impedance. Figure B 7.3-1 shows a parallel resonant LC circuit (R represents the resistance of its coil) at a frequency of 1000 KHz, $X_L = X_C$ resulting in resonance. This circuit is often referred to as a "tank circuit." Figure B 7.3-2, the response curve of I_T, shows that the line current drops to a minimum at resonance. Figure B 7.3-3, the response curve of Z_T, shows that it is at maximum at resonance.

The formula for determining the frequency of a parallel resonant circuit, is the same as the series resonant circuit.

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

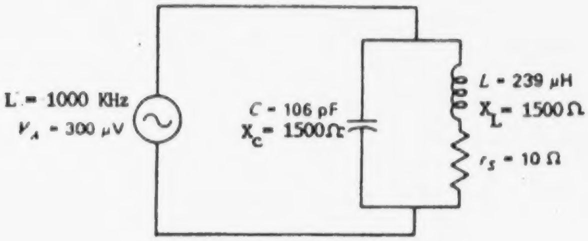


Figure B 7.3-1

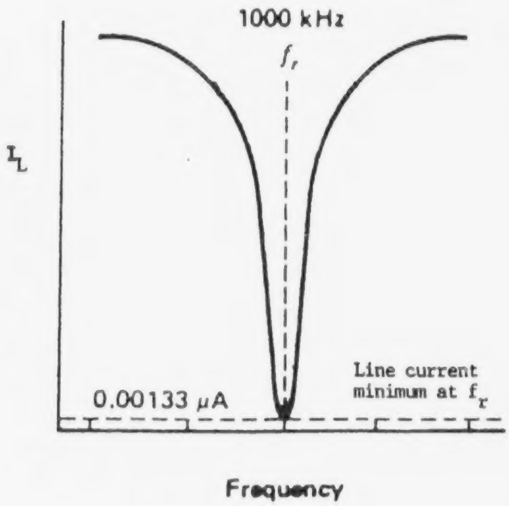


Figure B 7.3-2

INFORMATION SHEET B 7.3 CONT'D.

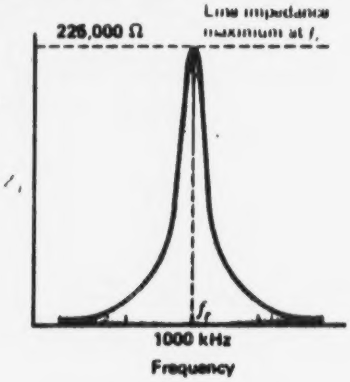


Figure B 7.3-3

From previous studies, the Q of a coil is the rate of its reactance divided by the resistance of the coil. The formula:

$$Q = \frac{X_L}{R}$$

To determine the impedance of a parallel resonant circuit, you can use the Q of the coil and its reactance: $Z = X_L \times Q$. Referring to Figure B 7.3-1:

$$Q = \frac{X_L}{R} = \frac{1500}{10} = 150.$$

The tank circuit: $Z = XQ = (1500) \times (150) = 225{,}000$ ohms.

Another method to determine the Z of a tank circuit, is the application of Ohm's Law. $Z = \frac{V}{I}$

Referring to Figure B 7.3-2:

$$Z = \frac{V}{I} = \frac{300\ \mu v}{.00133\ \mu a} = 225{,}000 \text{ ohms}$$

Note that using either method the impedance of the tank circuit is 225,000 ohms.

When an LC circuit is resonant at one frequency, this is true for maximum resonance effect. However, other frequencies close to f_r are effective. How wide this band of frequencies is depends on the Q of the circuit. The width of the resonant band of frequencies is called the bandwidth (BW) of the tuned circuit. The bandwidth depends on f_r and Q. Therefore: $BW = \frac{f}{Q}$

For example: A circuit resonant at 800 KHz, has a Q of 80. Using the formula $BW = \frac{f_r}{Q}$, $BW = \frac{800 \text{ KHz}}{.80} = 10$ KHz.

INFORMATION SHEET B 7.3 CONT'D.

This means the bandwidth is 10 KHz. Refer to Figure B 7.3-4 for an illustration of various bandwidths.

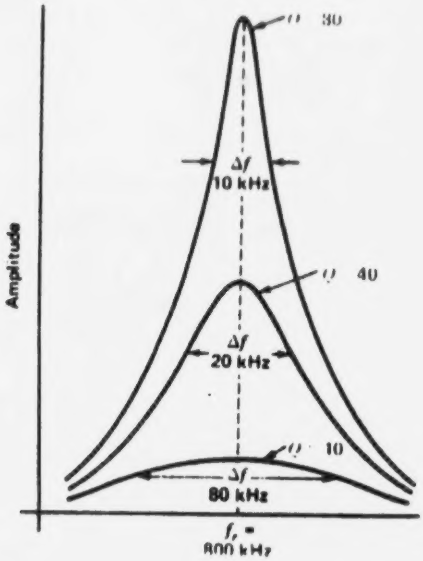


Figure B 7.3-4

ACTIVITY SHEET

B 7.4

1. Some resistance will always exist in a tank circuit. Generally, the largest source of AC resistance is the resistance of the ____________________.

2. At resonance, the tank circuit current is ________________.

   A. High
   B. Low

3. At resonance, the line current is ________________.

   A. High
   B. Low

4. To increase f_r, must the C increase or decrease?

5. A parallel LC circuit is tuned to 200 KHz with a 350 μh, L has a measured Z of 17,600 ohms. Calculate Q.

6. A circuit resonant at 2000 KHz has a Q of 100. Calculate the total bandwidth.

7. A circuit with a Q of 40 is resonant at 10 MHz. Calculate the half power bandwidth.

8. Is a parallel resonant circuit inductive or capacitive below resonance?

9. What is f_r for 1000 pF of C and 1 mH of L?

10. What is f_r for 250 pF of C and 1 mH of L?

ACTIVITY SHEET B 7.4

ANSWER SHEET

1. Coil
2. A
3. B
4. Less
5. 40
6. 20 KHz
7. 250 KHz
8. Inductive
9. 159 KHz
10. 318 Khz

ACTIVITY SHEET

B 7.5

RESONANT PROBLEMS

1. Calculate the resonant frequency of a series RLC circuit if R = 10 ohms, L = 1 mH, and C = 0.02 microfarads.

2. What value of inductance must be connected in series with a 500 picofarad capacitor if the desired resonant frequency is 100 Khz?

3. What must be the value of L in Problem 2 for a resonant frequency of 2 Mhz?

4. What value capacitance must be connected in series with a 200-micro H inductance in order to obtain a resonant frequency of 1.5 Mhz?

5. A 400 micro H inductor having a resistance of 20 ohms is connected in series with a 1000-pF capacitor. Calculate the Circuit Q.

6. A series RCL circuit consists of a 5000-pF capacitor connected in series with a 200-micro H inductor having a resistance of 25 ohms. Calculate the resonant frequency, the circuit Q, and the voltage across the capacitor at resonance if the circuit is connected to a 50 mV signal generator.

7. Calculate the anti-resonant frequency of an ideal parallel RCL circuit if R = 2K ohms, L = 1 mH, and C = 0.02 microfarads.

8. What value of capacitance must be connected in parallel with an ideal inductance of 5.06 mH if the desired anti-resonant frequency is 0.1 Mhz?

9. A 0.03-microfarad capacitor is connected in parallel with a 700-micro henry inductor having a resistance of 100 ohms. Calculate the anti-resonant frequency, the circuit Q and the bandwidth.

10. If the bandwidth in Problem 9 must be less than 1.0 Khz, what must be the maximum value of the inductor's resistance?

ACTIVITY SHEET B 7.5

ANSWER SHEET

1. $$F = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{1x10^{-3}*2x10^{-3}}} = \underline{35.6\ \text{Khz}}$$

2. $$L = \frac{1}{4\pi^2F^2} = \frac{1}{4\pi^2x10^{10}x5x10^{-10}} = \underline{5.07\ \text{mH}}$$

3. $$L = \frac{1}{4\pi^2*4*10^{12}*5*10^{-10}} = \underline{12.7\ \mu\text{H}}$$

4. $$C = \frac{1}{4\pi^2F^2L} = \frac{1}{4\pi^2*1.5^2*10^{12}*2x10^{-4}} = \underline{56.3\text{pF}}$$

5. $$F = \frac{1}{2\pi\sqrt{LC}} \text{ or } \omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{4x10^{-4}x10^{-9}}} = \underline{1.58x10^6}$$

$$Q = \frac{\omega L}{R} = \frac{1.58x10^6*4x10^{-4}}{20} = 31.6$$

6. $$F = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{2x10^{-4}x5x10^{-9}}} = \underline{159\text{Khz}}$$

$$Q = \frac{\omega L}{R} = \frac{2\pi\ x159x10^3x2x10^{-4}}{25} = \underline{7.99}$$

$$V_C = Q_s = 7.99*50\text{mV} = 400\text{mV}$$

7. $$F = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{1x10^{-3}*2x10^{-8}}} = \underline{35.6\text{Khz}}$$

ACTIVITY SHEET B 7.5 CONT'D.

8. $$C = \frac{1}{4\pi^2F^2L} \qquad \frac{1}{4\pi^2 * 10\ 10 * 5.06\text{x}10^{-3}} = \underline{500\text{pF}}$$

9. $$F_{ar} = \frac{1}{2\pi\sqrt{LC}}\sqrt{1 - \frac{R_L{}^2C}{L}} = \frac{1}{2\pi\sqrt{7\text{x}10^{14}\text{x}3\text{x}10^{-8}}} \cdot$$

$$\sqrt{1 - \frac{1-10^4\text{x}3\text{x}10^{18}}{7\text{x}10^{-4}}} = 3.47\text{x}10^4 \quad \sqrt{1-0.429} = \underline{26.2\text{ Khz}}$$

$$Q = \frac{\omega L}{R} = \frac{26.2\text{x}10^3\text{x}2\pi\ \text{x}7\text{x}10}{100} \qquad Q = \underline{1.15}$$

$$BW = \frac{F_{ar}}{Q} \quad \frac{26.2\text{ Khz}}{1.15} = \underline{22.8}\ \underline{\text{Khz}}$$

10. Assume $Q > 10$ Ideal F_{ar} of 34.7 Khz.

$$Q = \frac{F_{ar}}{BW} = \frac{34.7\text{ Khz}}{1\text{Khz}} = \underline{34.7} \text{ Therefore: } R = \frac{\omega L}{Q}$$

$$\frac{2\pi * 34.7\text{x}10^3\text{x}7\text{x}10^{-4}}{34.7} \qquad \text{So, } R = 4.4\ \Omega$$

PROGRAM: ELECTRONICS

TASK: SERIES AND PARALLEL RESONANT CIRCUITS

TASK # B 7.6

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Using schematics, analyze, construct, and troubleshoot series and parallel resonant circuits.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and you must score at least 7 out of 8 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 7 out of 8 points, or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

SERIES AND PARALLEL RESONANT CIRCUITS

B 7.6

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
1.	Does circuit function correctly?	Y	N
*2.	Was circuit wired according to the schematic?	Y	N
3.	Are the connections correct?	Y	N
*4.	Was the necessary data recorded?	Y	N
5.	Was the correct equipment used?	Y	N
*6.	Was the equipment used properly?	Y	N
*7.	Were safety precautions followed?	Y	N
8.	Was the equipment returned to proper storage?	Y	N

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

SCORE ______

SERIES AND PARALLEL RESONANT CIRCUITS

EXAM B 7.7

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on parallel resonant circuits. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C or D) in the numbered blank space on your answer sheet. Do not write on this test!!! To master this exam you must answer 16 out of 20 items correctly, or 80%.

SERIES AND PARALLEL RESONANT CIRCUITS

EXAM B 7.7

1. The resonant frequency of an LC circuit is 1000 KHz. If L is doubled but C is reduced to one-eighth of its original value, the resonant frequency then is __________.

   A. 250 KHz
   B. 500 KHz
   C. 1000 KHz
   D. 2000 KHz

2. What value of L is necessary with a C of 50 pF for a series resonance at 1 MHz?

   A. .1 mh
   B. 5.07 μh
   C. 1 mh
   D. 507 μh

3. Referring to Question 2, what size L is needed for a resonant circuit of 4 MHz?

   A. 1 mh
   B. 128 μh
   C. 31.7 mH
   D. 25.3 μh

4. A tuned circuit has an f_r of 64 KHz and a Q of 16. The bandwidth is __________ KHz.

   A. 2
   B. 4
   C. 6
   D. 8

5. Referring to Question 4, the circuit responds to frequencies between __________ KHz and __________ KHz.

   A. 61, 65
   B. 62, 66
   C. 60, 68
   D. 56, 72

EXAM B 7.7 CONT'D.

6. The bandwidth of a parallel resonant circuit can be broadened by adding a __________ in parallel with the tank.

   A. capacitor
   B. inductor
   C. capacitor
   D. resistor

7. At resonance, the phase equals ___________.

   A. 0°
   B. 90°
   C. 180°
   D. 270°

8. In a series LC circuit at the resonant frequency the ________________.

   A. current is minimum
   B. voltage across C is minimum
   C. impedance is maximum
   D. current is maximum

9. A coil has 1000 ohms X_L and 5 ohms resistance. The Q equals __________.

   A. .005
   B. 5
   C. 200
   D. 1000

10. In a series resonance circuit the line current is __________.

   A. low
   B. high

11. In a parallel resonance circuit the line current is ___________.

   A. low
   B. high

12. Whether series or parallel, when X_L equals X_C the circuit is resonant.

   A. true
   B. false

EXAM B 7.7 CONT'D.

13. The bandwidth of a series resonant circuit is the point at which the current falls to __________ percent of its maximum.

    A. 50
    B. 70.7
    C. 75
    D. 80

14. In parallel resonance the higher the resistance the lower the Q and the broader the _________ will be.

    A. X_L
    B. X_C
    C. bandwidth

15. In series resonance the impedance is maximum at f_r.

    A. true
    B. false

Figure B 7.7-1 will be used for Problems 16 through 20.

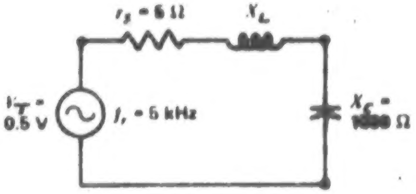


Figure B 7.7-1

16. How much is X_L?

    A. 628 ohms
    B. 1000 ohms
    C. 2000 ohms
    D. 5000 ohms

17. Calculate the Q.

    A. 1000
    B. 20
    C. 50
    D. 200

18. Calculate the bandwidth.

   A. 25 Hz
   B. 250 Hz
   C. 25 KHz
   D. 100 Hz

19. Calculate V_L.

   A. 100 V
   B. 50 V
   C. 628 V
   D. 10 V

20. Calculate V_C.

   A. 50 V
   B. 10 V
   C. 100 V
   D. 628 V

EXAM KEY B 7.7

1. D
2. D
3. C
4. B
5. B
6. D
7. A
8. D
9. C
10. B
11. A
12. A
13. B
14. C
15. B
16. B
17. D
18. A
19. A
20. C

ELECTRONICS

ANALYZING AC CIRCUITS

B 8: FILTER CIRCUITS

TASK: Using schematics analyze, construct, and troubleshoot filter circuits.

PURPOSE: Electronic circuits often have currents of different frequencies corresponding to voltages of different frequencies. The reason is that a source produces current with the same frequency as the applied voltage. As examples, the input of an audio circuit will have both high and low frequencies; an RF circuit will have a wide range of frequencies in its input. In many applications it becomes necessary to reject one frequency or a band of frequencies. This is the purpose of a filter. This task will cover the four most useful filters: low-pass filters, high- pass filters, band-pass filters and band-stop filters.

OBJECTIVE: Given the necessary information and resources, you will analyze, construct and troubleshoot various filters. To complete this task you must score at least 80% on a written exam and laboratory performance.

ESTIMATED CLASS TIME: 8 HOURS

FILTER CIRCUITS

LEARNING STEPS

B 8

READ: Information Sheet B 8.1, "Low-Pass and High-Pass Filters."

READ: Information on low-pass and high-pass filters from the following resource list.

COMPLETE: Activity Sheet B 8.2, "Low-Pass and High-Pass Filters."

READ: Information Sheet B 8.3, "Band-Pass and Band-Stop Filters."

READ: Information on band-pass and band-stop from the following resource list.

COMPLETE: Activity Sheet B 8.4, "Band-Pass and Band-Stop Filters."

COMPLETE: Activity Sheet B 8.5, "Filter Problems."

COMPLETE: Lab Performance Checklist B 8.6.

COMPLETE: Exam B 8.7.

RECOMMENDED EQUIPMENT

Dual-trace oscilloscope
VOM or DVM
AF-RF generator
Various resistors, inductors, and capacitors

FILTER CIRCUITS

RESOURCES

B 8

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1984). 5th ed.
2 Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). 5th ed.
3. Badrkhan and Lark, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984).
4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS (McGraw-Hill, 1984). 2nd ed.
5. AC ELECTRONICS (Heath Company, 1982). Nineteenth Printing.

INFORMATION SHEET

B 8.1

LOW-PASS AND HIGH-PASS FILTERS

A "low-pass filter", as the name implies, permits the flow of current below a given frequency. Frequencies above the specific frequency will be "attenuated" or blocked. Figure B 8.1-1 shows a simple low-pass filter. The circuit contains a capacitor and a resistor. Figure B 8.1-2 shows the performance of the low-pass filter. Note that the cut-off frequency is defined to be at 70.7% on the curve. Higher frequencies will still be passed, but will be attenuated greatly. As the frequencies go higher the attenuation is greater.

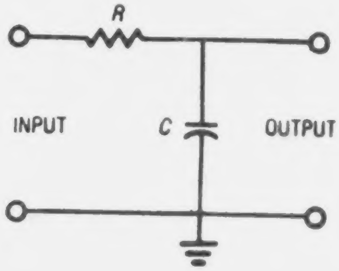


Figure B 8.1-1

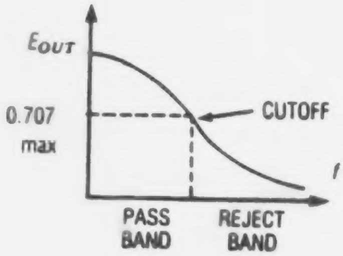


Figure B 8.1-2

The capacitor used in Figure B 8.1-1 is called a "by-pass capacitor." It offers a by-pass or shunt (low-impedance) to frequencies above the pass level of the circuit.

Another type of low-pass filter is shown in Figure B 8.1-3. In this type of circuit the inductor has low impedance at low frequencies. As the frequency is increased, the reactance goes up, blocking the higher frequencies.

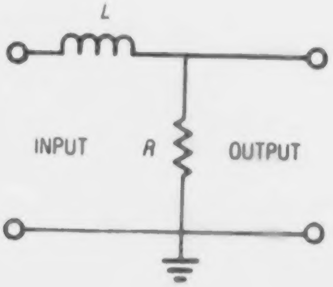


Figure B 8.1-3

The same principles can be applied to several other configurations of low-pass filters. Figure B 8.1-4 shows the "inverted inductor" type filter. This gives a sharper cut-off. The "T-Type" filter (Figure B 8.1-5) has a steeper cut-off curve, due to the inductor added on the output. In terms of simple low-pass filters, Figure B 8.1-6 (II type) has the steeper cut-off curve.

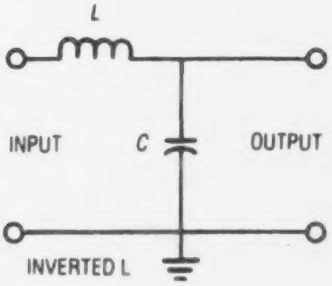

L
INPUT
C
OUTPUT
INVERTED L

Figure B 8.1-4

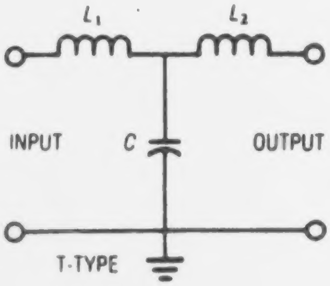

L₁
L₂
INPUT
C
OUTPUT
T-TYPE

Figure B 8.1-5

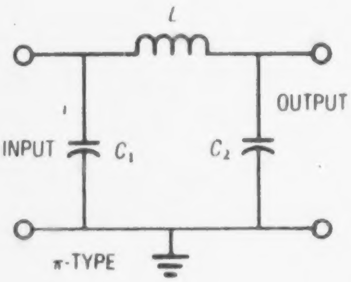

L
OUTPUT
INPUT
C₁
C₂
π-TYPE

Figure B 8.1-6

High-pass filters do just the opposite of the low-pass. They block or attenuate all frequencies up to a given level, then pass all frequencies above the cut-off frequency. The simple RC high-pass (shown in Figure B 8.1-7) is connected just the reverse of the low-pass RC circuit. Figure B 8.1-8 is the performance curve for a high-pass filter.

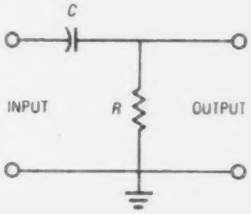

C
INPUT
R
OUTPUT

Figure B 8.1-7

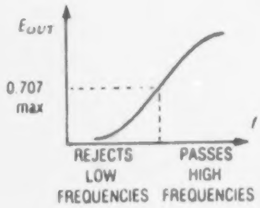


Figure B 8.1-8

Several circuit configurations can be used for high-pass filters. They include the inverted L, T-Type and Type, shown in Figures B 8.1-9, B 8.1-10, and B 8.1-11.

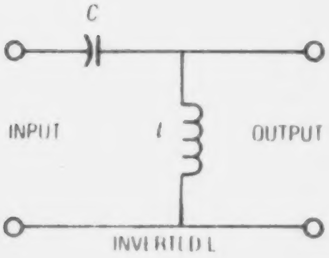

C
INPUT
L
OUTPUT
INVERTED L

Figure B 8.1-9

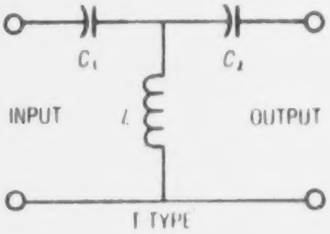

C₁
C₂
INPUT
L
OUTPUT
T TYPE

Figure B 8.1-10

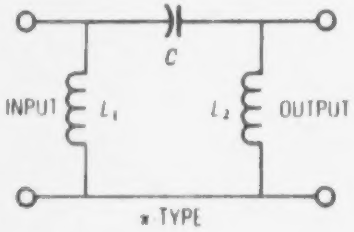

C
INPUT
L₁
L₂
OUTPUT
π TYPE

Figure B 8.1-11

ACTIVITY SHEET

B 8.2

1. A circuit composed of components that is designed to pass some frequencies and block other is referred to as a _________________________.

2. A high-pass filter passes all frequencies___________________ its cut-off frequency.

   A. Above
   B. Below

3. A low-pass filter blocks all frequencies___________________ its cut-off frequency.

   A. Above
   B. Below

4. For a high-pass LC filter, the _______________ is connected in series with the load.

5. In a low-pass LC filter the _______________ is connected in series with the load.

Match the following response curves with the proper filters. See Figure B 8.2-1.

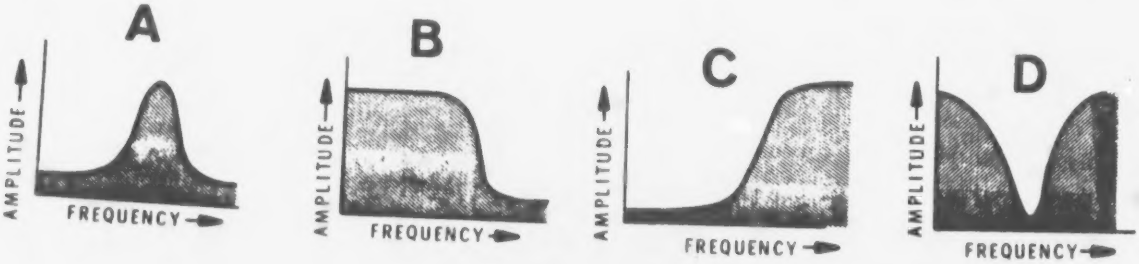


Figure B 8.2-1

6. Figure B 8.2-1B is the response curve for a _______________ filter.

7. Figure B 8.2-1C is the response curve for a ________________ filter.

ACTIVITY SHEET B 8.2

ANSWER SHEET

1. Filter
2. A
3. A
4. capacitor
5. coil
6. low-pass
7. high

INFORMATION SHEET

B 8.3

BAND-PASS AND BAND-STOP FILTERS

"Band-pass" filters have the features of both low and high pass filters. These circuits will block both high and low frequencies, and the intermediate band of frequencies will be passed.

The band-pass filter is basically a resonant circuit. If series resonant circuits are used, they offer a low impedance at and near the resonant frequency. This allows a band of frequencies to pass.

Since the quality of a resonant circuit will determine selectivity of the circuit, the Q of a band-pass filter will determine how sharp the selectivity will be.

Figure B 8.3-1 shows the circuit for a series resonant band-pass circuit. Figure B 8.3-2 illustrates the typical response curve of the band-pass filter.

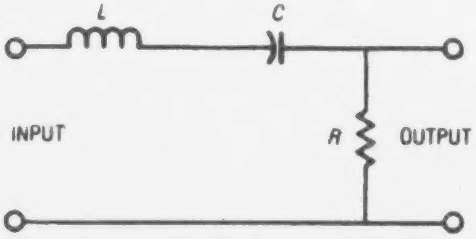


Figure B 8.3-1

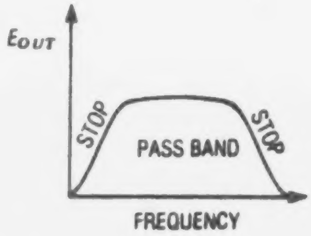


Figure B 8.3-2

Another form of band-pass filter that can be used is the "parallel resonant circuit" (shown in Figure B 8.3-3). However, the parallel resonant circuit must be connected across the output. At resonance, the tank circuit has a high impedance at the resonant frequency, developing a high output voltage.

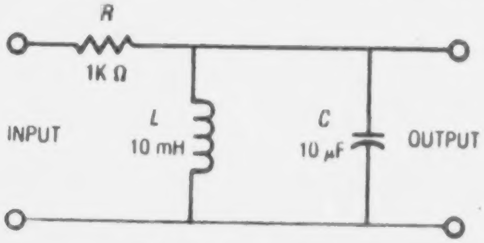


Figure B 8.3-3

Below resonance, the reactance of the coil will be quite low, allowing those currents to flow to ground. Above resonance, the reactance of the capacitor will be low, allowing those currents to flow to ground. The width of the band-pass will depend on the Q of the circuit.

Another type of filter used in electronics is the "band-stop" filter. The band-stop filter is designed to stop a band of frequencies, allowing lower and higher frequencies to pass. This can be achieved by either series or parallel resonance circuits. Figure B 8.3-4 shows a "series resonant" type filter. Here the low impedance at the resonant frequency causes those frequencies to be effectively shorted to ground. So the output at these frequencies is very low. The response of a band-stop filter is shown in Figure B 8.3-5.

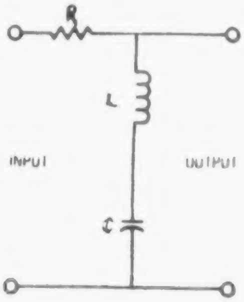


Figure B 8.3-4

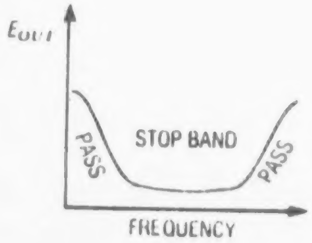


Figure B 8.3-5

A band-stop filter can also be constructed with a parallel resonant circuit. However, the tank circuit is now connected across the output. At resonance, the circuit has a high impedance, developing voltage across the load at those frequencies. At frequencies above and below the resonant frequency, the coil or capacitor will present a low-impedance path to ground. Figure B 8.3-6 shows the circuit for a band-stop filter using a parallel resonant circuit.

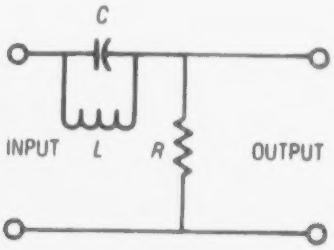


Figure B 8.3-6

ACTIVITY SHEET

B 8.4

1. Circuits that are designed to stop undesired frequencies are called ______________________.

2. A series resonant circuit connected across the load would be a _________________ filter.

3. If only a certain band of frequencies was wanted, you would need a _______________ filter.

4. If a parallel resonant circuit is used across the load, the filter would be of the ________________ type.

Referring to Figure B 8.4-1, identify the following:

5. Figure B 8.4-1B represents a _________________ filter.

6. Figure B 8.4-1C represents a _________________ filter.

7. Figure B 8.4-1E represents a _________________ filter.

8. Figure B 8.4-1F represents a _________________ filter.

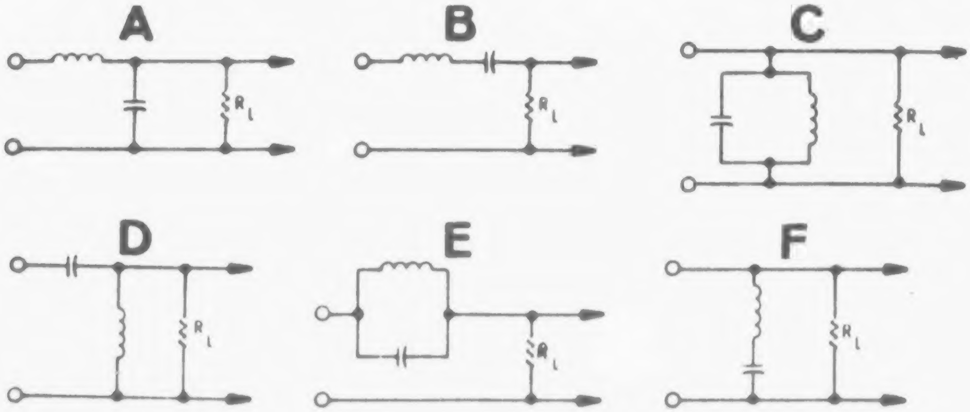


Figure B 8.4-1

ACTIVITY SHEET B 8.4

ANSWER SHEET

1. band-stop
2. band-stop
3. band-pass
4. band-pass
5. band-pass
6. band-pass
7. band-stop
8. band-stop

ACTIVITY SHEET

B 8.5

FILTER PROBLEMS

1. Calculate the value of C in Figure B 8.5-1 a frequency of 455 Khz if L = 560 micro h. Assume an ideal inductor.

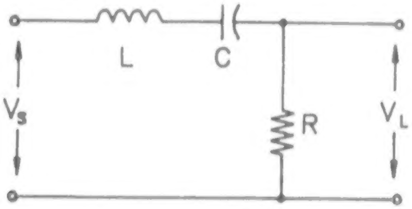


Figure B 8.5-1

2. Repeat Problem 1 for a frequency of 1 Mhz.

3. Calculate the value of C in Figure B 8.5-2 to reject a frequency of 455 Khz if L = 560 micro h. Again, assume an ideal inductor.

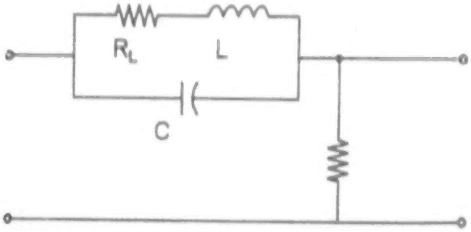


Figure B 8.5-2

4. Calculate the values of L_s in Figure B 8.5-3 to pass a frequency of 1 Mhz and reject a frequency of 500 KHz if C_s = 100pF.

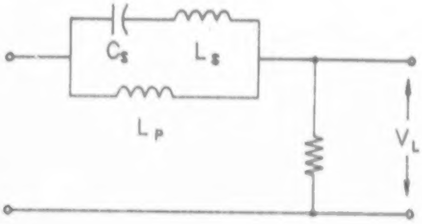


Figure B 8.5-3

ACTIVITY SHEET B 8.5 CONT'D.

5. Calculate values of L_s and C_p in Figure B 8.5-4 to pass a frequency of 1 Mhz and reject a frequency of 2 Mhz if C_s = 100 pF.

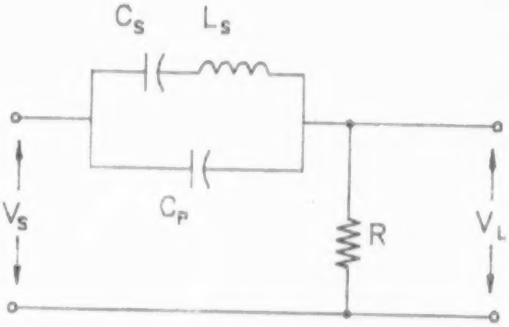


Figure B 8.5-4

ACTIVITY SHEET B 8.5
ANSWER SHEET

1. $F = \frac{1}{2\pi LC}$ SO $C = \frac{1}{4\pi^2 F^2 L}$

$$= \frac{1}{4\pi^2 * 4.55^2 * 10^{10} * 5.6 * 10^{-4}} = 218.5PF$$

2. $C = \frac{1}{4\pi^2 * 10 * 5.6 * 10^{-4}} = 45.2PF$

3. $Far = \frac{1}{2\pi LC}$ $C = \frac{1}{4\pi^2 F^2 L}$ $= \frac{1}{4\pi^2 * 4.55 * 10^{10} * 5.6 * 10^{-4}}$

$$= 218.5pF$$

4. $L_s = \frac{1}{4\pi F^2 C} = \frac{1}{4\pi^2 * 10^{12} * 2 * 10^{-10}} = 126\mu H$

at 500 KHz, $X_s = j\ (X_{LS} - X_{CS}) = j(2\pi * 5 * 10^5 * 1.26x10^{-4}$

$\frac{\quad}{-2}$ $\frac{1}{x5x10^5x10^{-10}}$ $= j(398-3183) = -j2786$ so $L_p = \frac{X_p}{}$

$$= \frac{2786}{2\pi * 5 * 10^5} = 887\ H$$

5. $L_s = \frac{1}{4\pi^2 F^2 C} = \frac{1}{4\pi^2 * 10^{12} * 10^{-10}} = 253\mu H$

at 2 Mhz $X_s = j(2\pi * 210_6 * 253 * 10^{-6}) - \frac{1}{2\pi * 2 * 10^6 * 10^{-10}}$

$= j\ (3179-796) = j2383$ so need cap in paralledl

$C = \frac{1}{\omega_{xc}} = \frac{1}{2\pi * 2 * 10^6 * 2383} = 33.4pF$

PROGRAM: ELECTRONICS

TASK: FILTER CIRCUITS

TASK # B 8.6

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Using schematics, analyze, construct, and troubleshoot filter circuits.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 55 minutes and you must score at least 6 out of 8 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student willcontact you when ready for evaluation. The student must complete the performance within 55 minutes and must score 6 out of 8 points, or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

FILTER CIRCUITS

B 8.6

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Does the circuit function correctly?	Y N
*2.	Was the circuit wired according to schematic?	Y N
3.	Are the connections correct?	Y N
4.	Was necessary data recorded?	Y N
*5.	Was correct equipment used?	Y N
6.	Was equipment used properly?	Y N
*7.	Were safety precautions followed?	Y N
8.	Was the equipment returned to proper storage?	Y N

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

SCORE ______

FILTER CIRCUITS

EXAM B 8.7

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on filter circuits. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C or D) in the numbered blank space on your ANSWER SHEET. DO NOT WRITE ON THIS TEST!! To master this exam you must answer 16 out of 20 items correctly, or 80%.

FILTER CIRCUITS

EXAM B 8.7

1. In the high-pass filter all frequencies above the cut-off frequency are blocked.

   A. True
   B. False

2. The band-pass filter uses a series resonant circuit.

   A. True
   B. False

3. If a filter uses a series resonant circuit across the load, it is a band-stop filter.

   A. True
   B. False

4. With input frequencies from direct current to 15 Kh a low-pass filter has the most output at ________________.

   A. Direct current
   B. 15 Hz
   C. 150 Hz
   D. 15,000 KHz

5. Which of the following is a low-pass filter?

   A. Series C, Shunt L
   B. Series L, Shunt C
   C. T-Type, Series C, Shunt L

6. With input frequencies from DC to 15 KHz, a high-pass filter has maximum output at ______________.

   A. Direct current
   B. 15 Hz
   C. 150 Hz
   D. 15,000 KHz

7. A series resonant circuit has ______________.

   A. Low I, High Z
   B. Low I, Low Z
   C. High I, Low Z
   D. High I, High Z

8. A parallel resonant circuit has ________________.

A. Low I, High Z
B. Low I, Low Z
C. High I, Low Z
D. High I, High Z

9. An L-Type filter with a parallel resonant LC circuit in series with the load is a band-stop filter.

A. True
B. False

10. Resonant circuits can only be used as band-stop filters.

A. True
B. False

For Questions 11 through 14, use Figure B 8.7-1:

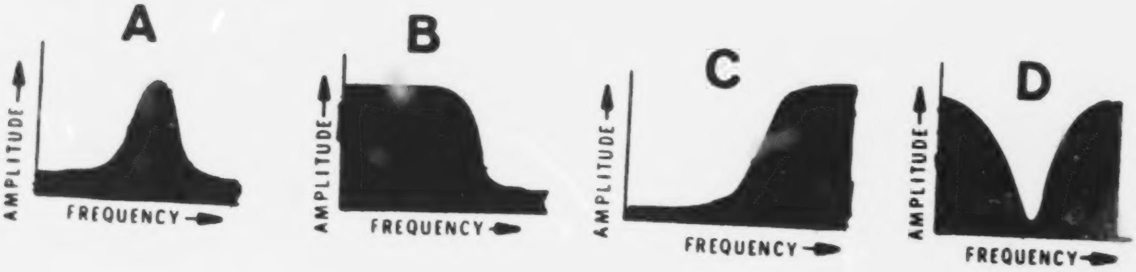


Figure B 8.7-1

11. A low-pass filter output is represented by ________________.

A. A
B. B
C. C
D. D

12. A high-pass filter output is represented by ______________.

A. A
B. B
C. C
D. D

13. A band-stop filter output is represented by ________________.

A. A
B. B
C. C
D. D

14. A band-pass filter output is represented by ________________.

A. A
B. B
C. C
D. D

For Questions 15 through 20, use Figure B 8.7-2:

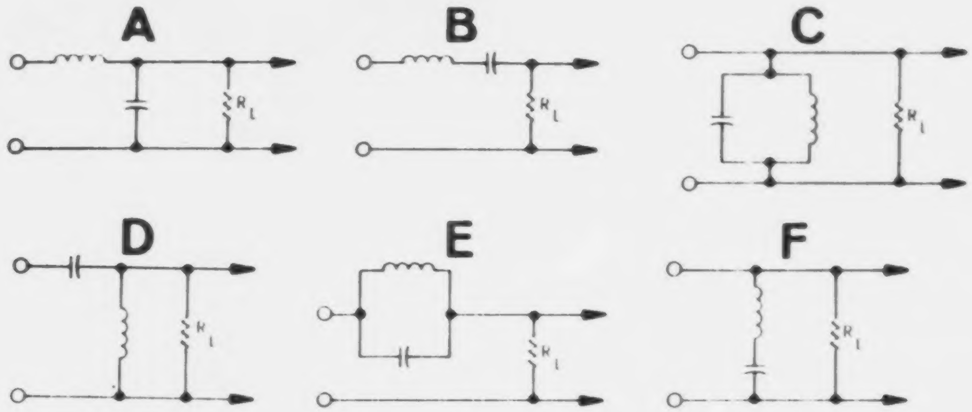


Figure B 8.7-2

15. Figure A is the circuit for a _______________ filter.

A. Band-Pass
B. Band-Stop
C. Low-Pass
D. High-Pass

16. Figure B is the circuit for a _______________ filter.

A. Band-Pass
B. Band-Stop
C. Low-Pass
D. High-Pass

17. Figure C is the circuit for a ______________ filter.

    A. Band-Pass
    B. Band-Stop
    C. Low-Pass
    D. High-Pass

18. Figure D is the circuit for a ______________ filter.

    A. Band-Pass
    B. Band-Stop
    C. Low-Pass
    D. High-Pass

19. Figure E is the circuit for a ______________ filter.

    A. Band-Pass
    B. Band-Stop
    C. Low-Pass
    D. High-Pass

20. Figure F is the circuit for a ______________ filter.

    A. Band-Pass
    B. Band-Stop
    C. Low-Pass
    D. High-Pass

FILTER CIRCUIT

EXAM KEY B 8.7

1. B
2. B
3. A
4. A
5. B
6. D
7. C
8. A
9. A
10. B
11. B
12. C
13. D
14. D
15. C
16. A
17. A
18. D
19. B
20. B

ELECTRONICS

ANALYZING AC CIRCUITS

B 9: DELTA AND WYE THREE-PHASE POWER CIRCUITS

TASK: Analyze delta and wye three-phase power circuits.

PURPOSE: Some circuits are powered by batteries, some by the normal 120 volt circuit. However, some circuits, can convert from delta to wye; others can also convert from wye to delta.

OBJECTIVE: Given the necessary information and resources, you will analyze both delta and wye 3-phase power circuits, and be able to convert from one to the other. You must score at least 80% on a written exam and laboratory performance.

ESTIMATED CLASS TIME: 8 HOURS

DELTA AND WYE THREE PHASE POWER CIRCUITS

LEARNING STEPS

B 9

READ:	Information Sheet B 9.1, "Three-Phase Power Circuits."
READ:	Information on three-phase power circuits in one or more of the following resources.
COMPLETE:	Activity Sheet B 9.2, "Three-Phase Power Circuits."
COMPLETE:	Laboratory Performance Checklist B 9.3.
COMPLETE:	Exam B 9.4.

RECOMMENDED EQUIPMENT

Various three-phase transformers

VOM or DVM

DELTA AND WYE THREE-PHASE POWER CIRCUITS

RESOURCES

B 9

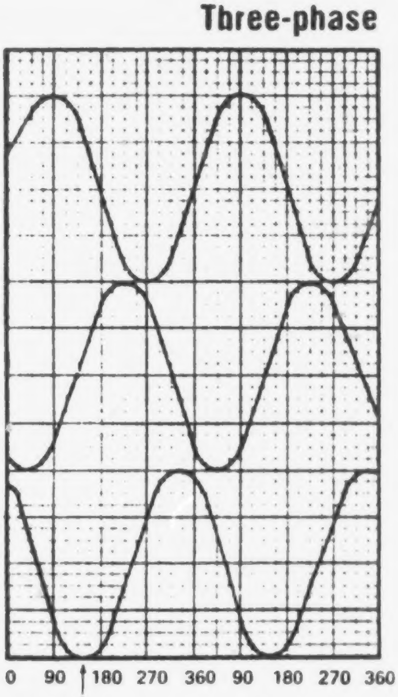
1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1984). 5th ed.
2. Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). 5th ed.
3. Badrkhan and Lark, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984).
4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS (McGraw-Hill, 1984). 2nd ed.
5. AC ELECTRONICS (Heath Company, 1982). Nineteenth Printing.

INFORMATION SHEET

B 9.1

THREE-PHASE POWER CIRCUITS

In an alternator with a rotor field, if the stator armature has three windings equally spaced around the circle, the three windings will generate output voltages 120° out of phase with each other. Figure B 9.1-1 shows the phase relationship of the three sine waves. The phasors for these voltages are shown in Figure B 9.1-2.



Three-phase power has voltages that peak each 120°.

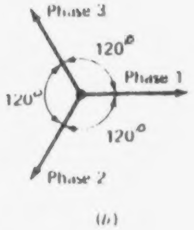


Figure B 9.1-1

Figure B 9.1-2

The advantage of three-phase AC voltage is that it is more efficient to distribute, and AC induction motors are self-starting with three-phase AC. Also the AC ripple is easier to filter in DC power supplies.

Figure B 9.1-3 shows how three windings are connected in the form of a Y (called "wye" or star). Any pair of terminals is across two coils in series; however, the total voltage will be 1.73 x 120, giving a total of 208 V. The 1.73 is due to the phase relationship of the two voltages.

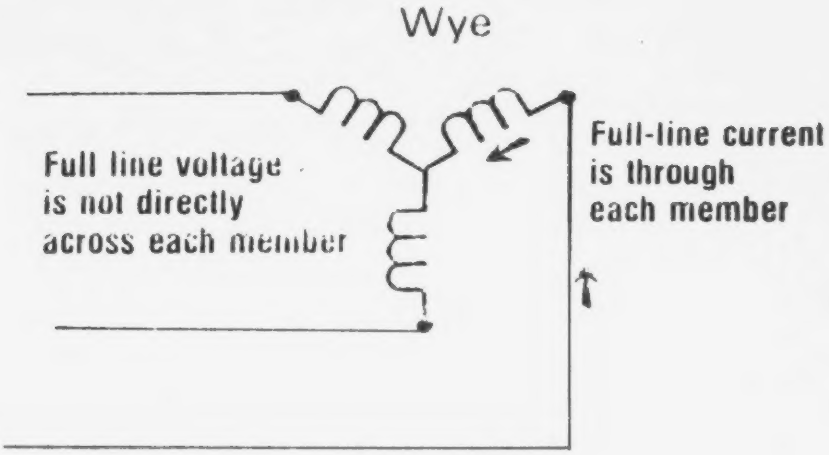

Wye
Full line voltage is not directly across each member
Full-line current is through each member

Figure B 9.1-3

One advantage to the three-phase wye connection is that the full-line current is through each member. The disadvantage is that full-line voltage is not directly across each member.

Figure B 9.1-4 shows the procedure to be used for identifying the size connector. In Figure B 9.1-5, the three windings are connected in the form of a "delta." Any pair of terminals is across one generator coil. However, the other coils are in a parallel leg. One advantage to delta is that the full voltage is across each member. The disadvantage is that full-line current is not available to each member.

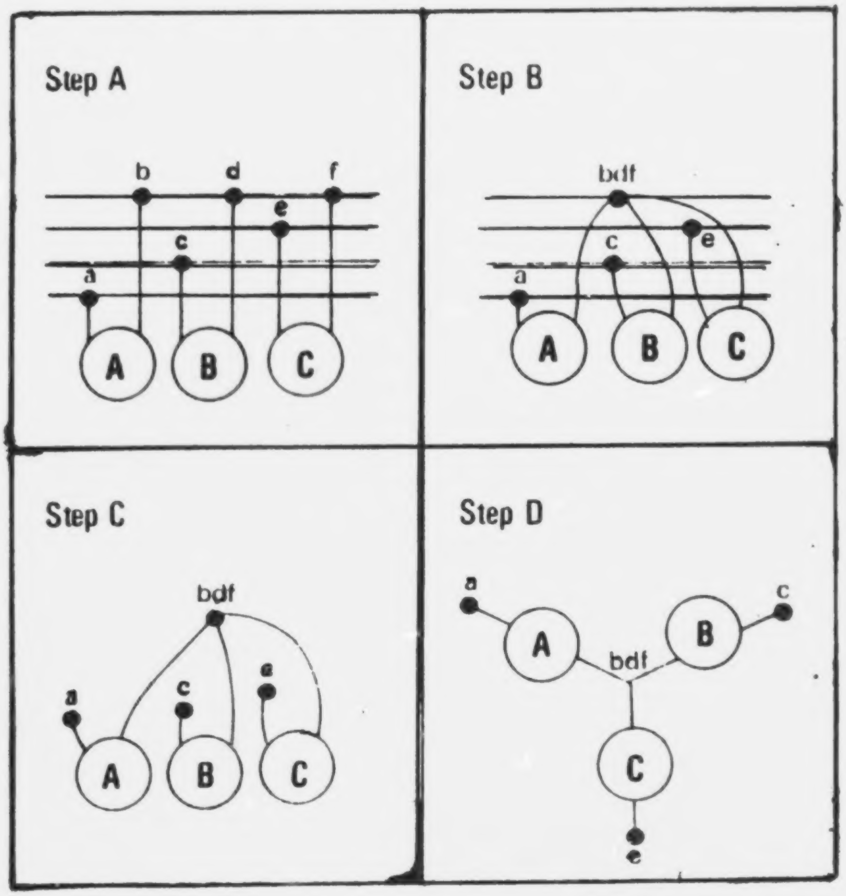

Step A
b
d
f
e
c
a
A
B
C
Step B
bdf
c
e
a
A
B
C
Step C
bdf
a
c
e
A
B
C
Step D
a
A
bdf
B
c
C
e

Figure B 9.1-4

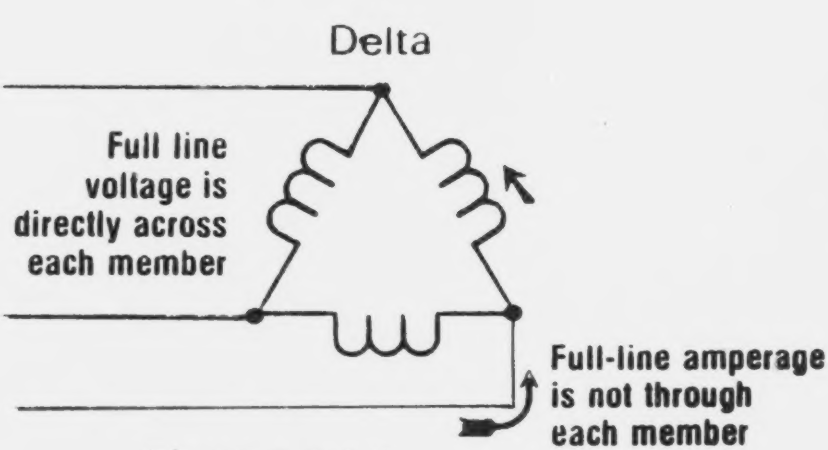

Delta
Full line voltage is directly across each member
Full-line amperage is not through each member

Figure B 9.1-5

The procedure for identifying the delta connection is shown in Figure B 9.1-6.

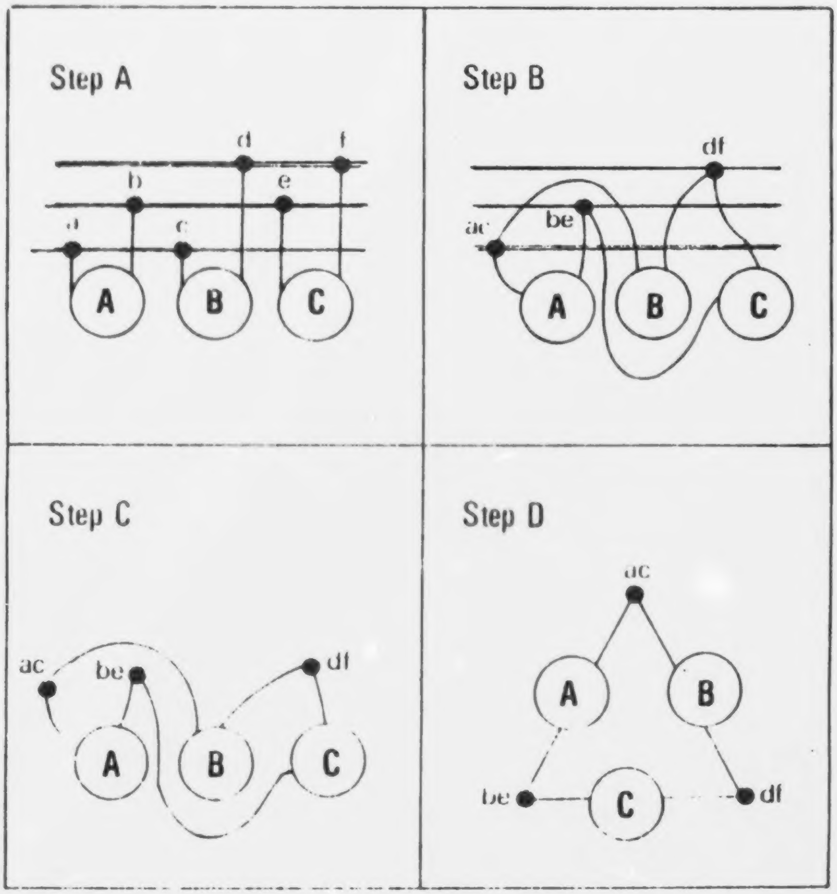

Step A
a
b
c
d
e
f
A
B
C
Step B
ac
be
df
A
B
C
Step C
ac
be
df
A
B
C
Step D
ac
A
B
be
C
df

Figure B 9.1-6

Another method of distributing three-phase power is shown in Figure B 9.1-7. This method uses four wires connected in a wye in which the fourth wire is the neutral wire. The advantage to this method of distribution is that the normal 208 V three-phase power is available, and in addition, between any leg and the neutral wire, 120 V single-phase is available for normal lighting circuits.

INFORMATION SHEET B 9.1 CONT'D.

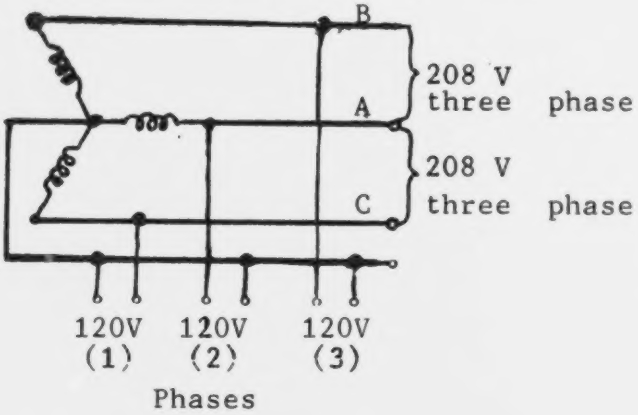

B
208 V
three phase
A
208 V
C
three phase
120V
(1)
120V
(2)
120V
(3)
Phases

Figure B 9.1-7

ACTIVITY SHEET

B 9.2

1. In three-phase power the voltages are _______________ degrees out of phase.

2. When wired as a wye connection, the full-line voltage is across each member.

   A. True
   B. False

3. One disadvantage to three-phase power is that the ripple voltage is harder to filter in DC power supplies.

   A. True
   B. False

4. One advantage to the delta connection is that the full voltage is across each member.

   A. True
   B. False

5. The power in a three-phase circuit, delta connected, is equal to E x I x 1.732.

   A. True
   B. False

6. Three-phase power can be delivered with four wires connected as a delta.

   A. True
   B. False

ACTIVITY SHEET B 9.2

ANSWER SHEET

1. 120
2. B
3. B
4. A
5. A
6. B

PROGRAM: ELECTRONICS

TASK: DELTA AND WYE THREE PHASE POWER CIRCUITS

TASK # B 9.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Analyze delta and wye three-phase power circuits.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and you must score at least 7 out of 8 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 7 out of 8 points, or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

DELTA AND WYE THREE PHASE POWER CIRCUITS

B 9.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES/NO
1.	Does the circuit function correctly?	Y N
*2.	Was the circuit wired according to the schematic?	Y N
3.	Are the connections correct?	Y N
4.	Was the necessary data recorded?	Y N
*5.	Was the correct equipment used?	Y N
*6.	Was the equipment used properly?	Y N
*7.	Were safety precautions followed?	Y N
8.	Was the equipment returned to the proper storage area?	Y N

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

______

DELTA AND WYE THREE PHASE POWER CIRCUITS

EXAM B 9.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on three-phase power circuits. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your ANSWER SHEET. DO NOT WRITE ON THIS TEST! To master this exam you must answer correctly 8 out of 10, or achieve a score equivalent to 80%.

DELTA AND WYE THREE PHASE POWER CIRCUITS

EXAM B 9.4

1. A delta-connected transformer has 5 amps on each line. The voltage is 208 V. The power of the circuit is __________ va.

   A. 5200
   B. 1040
   C. 1800
   D. 3090

2. In three-phase power, the three voltages are __________ out of phase.

   A. 0°
   B. 90°
   C. 120°
   D. 180°

Refer to Figure B 9.4-1 for Questions 3 through 6.

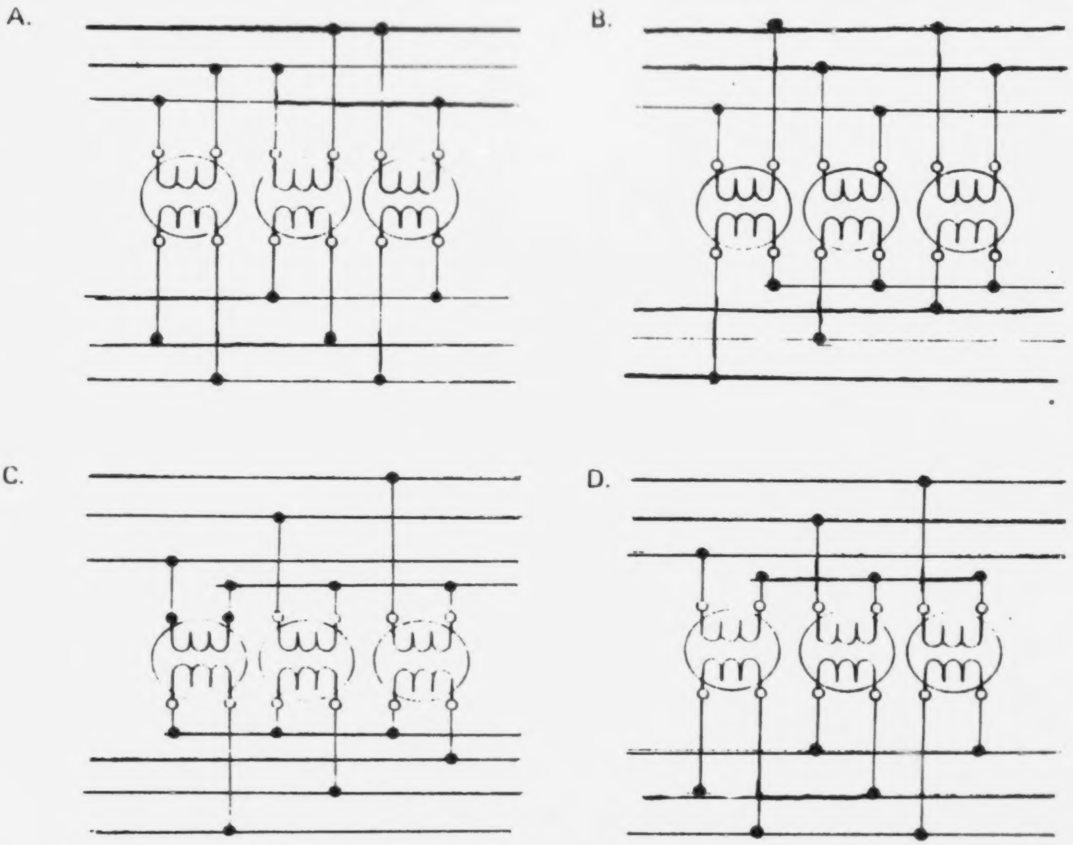


Figure B 9.4-1

3. Transformer A is connected ______________.

A. delta-delta
B. delta-wye
C. wye-wye
D. wye-delta

4. Transformer B is connected ______________.

A. delta-delta
B. delta-wye
C. wye-wye
D. wye-delta

5. Transformer C is connected ______________.

A. delta-delta
B. delta-wye
C. wye-wye
D. wye-delta

6. Transformer D is connected ______________.

A. delta-delta
B. delta-wye
C. wye-wye
D. wye-delta

Refer to Figure B 9.4-2

7. The transformer is connected ______________.

A. four-wire 120/280 volts delta-delta
B. four-wire 120/280 volts delta-wye
C. four-wire 120/208 volts wye-wye
D. four-wire 120/208 volts wye-delta

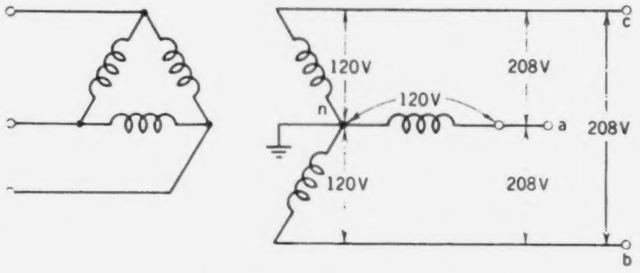
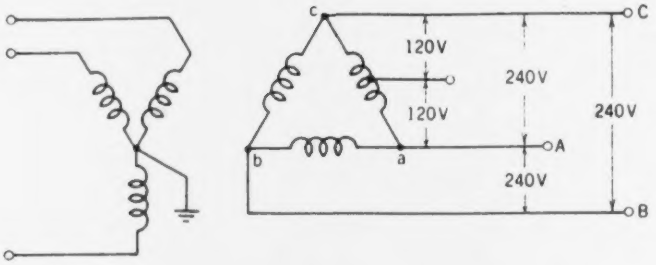


Figure B 9.4-2

Refer to Figure B 9.4-3



Refer to Figure B 9.4-3

8. The transformer is connected ________________.

A. four-wire delta-delta
B. four-wire delta-wye
C. four-wire wye-wye
D. four-wire wye-delta

9. A three-phase wye-connected motor has 5 amperes measured in each lead wire. The motor is rated at 460 volts. What power is the motor consuming?

A. 3984 va
B. 2300 va
C. 4157 va
D. 2400 va

10. A three-phase, delta-connected heater is operating on 240 volts. Each of the three elements measures 60 Ohms. What is the power consumed by the heater?

A. 960 va
B. 14,400 va
C. 7200 va
D. 1663 va

DELTA AND WYE THREE PHASE POWER CIRCUITS

EXAM KEY B 9.4

1. C
2. C
3. A
4. B
5. C
6. D
7. B
8. D
9. C
10. D

ELECTRONICS

ANALYZING SOLID STATE DEVICES

C 1: SEMICONDUCTOR DIODES

TASK:	Identify the properties of semiconductor materials and explore semiconductor diodes.
PURPOSE:	One of the basic parts of solid state devices is the semiconductor. It is essential that you have a thorough understanding of this subject. In this learning guide we will study the properties of semiconductor materials and their use in diodes.
OBJECTIVE:	Given laboratory supplies and equipment to master this task, you will pass the written exam and the laboratory performance checklist.

ESTIMATED CLASS TIME: 4 HOURS

SOLID STATE DEVICES

LEARNING STEPS

C 1: SEMICONDUCTOR DIODES

READ: Information Sheet C 1.1, "Semiconductor Materials."

READ: Information on semiconductor materials from the following resource list.

COMPLETE: Activity Sheet C 1.2, "Semiconductor Materials."

READ: Information Sheet C 1.3, "Germanium and Silicon Atoms."

READ: Information on germanium and silicon atoms from the following resource list.

COMPLETE: Activity Sheet C 1.4, "Germanium and Silicon Atoms."

READ: Information Sheet C 1.5, "Diode Biasing."

READ: Information on Diode Biasing from the following resource list.

COMPLETE: Activity Sheet C 1.6, "Diode Biasing."

READ: Information Sheet C 1.7, "Semiconductor Diode Characteristics."

READ: Information on semiconductor diode characteristics from the following resources list.

COMPLETE: Activity Sheet C 1.8, "Semiconductor Diode Characteristics."

COMPLETE: Lab Performance on exploring the properties of the diode. Contact your instructor.

COMPLETE: Lab Performance Checklist C 1.9. Contact your instructor.

COMPLETE: Exam C 1.10.

SEMICONDUCTOR DIODES

RESOURCES

C1

1. Grob, *BASIC ELECTRONICS* (McGraw-Hill, 1985). Fifth Edition.
2. Zbar and Malvino, *BASIC ELECTRONICS* (McGraw-Hill, 1983). Fifth Edition.
3. Badrkhan and Lark, *ELECTRONICS: PRINCIPLES AND APPLICATIONS* (South-Western Publishing Company, 1984).
4. Schuler, *ELECTRONICS PRINCIPLES AND APPLICATIONS* (McGraw-Hill, 1984). Second Edition.
5. *SEMICONDUCTOR DEVICES* (Heath Company, 1982). Eighteenth Printing.

RECOMMENDED EQUIPMENT

0-20 VDC Power Supply
DMM
VOLT-OHM Meter or Digital Multimeter

INFORMATION SHEET

C 1.1

SEMICONDUCTOR MATERIALS

The term semiconductor is used to describe any material that has characteristics which fall between those of insulators and conductors. In other words, a semiconductor is neither a good conductor nor a good insulator. Copper and silver carry current and are classified as conductors, while glass and rubber do not carry current and they are considered insulators. Conductors, insulators, and semiconductors contain atoms which are the smallest portion of an element that still exhibits all the characteristics of that element.

An atom with exactly eight electrons in the outer shell, called the "valence," is completely stable and will neither give up or accept electrons easily. With five or more electrons in the valence shell, it tries to fill the holes with electrons so it can reach a stable condition. Elements of this type make good insulators.

With exactly four electrons in the valence shell, it does not readily give up or accept electrons. This means it is not a good conductor. These elements we call "semiconductors." When a positive hole develops in the outer shell of one atom, it is possible for that atom to share a valence electron with another atom. This joining of atoms through the sharing of valence electrons is called a "bond." The resulting structure is known as a "molecule."

The two semiconductors best-suited for solid state electronic devices are germanium and silicon. See Figures C 1.1-1 and C 1.1-2.

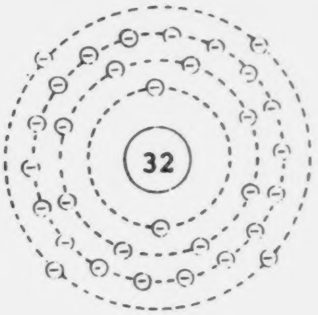


Figure C 1.1-1

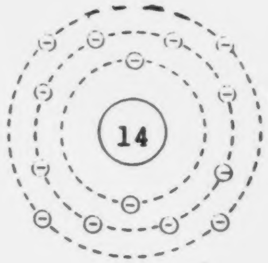


Figure C 1.1-2

INFORMATION SHEET C 1.1 CONT'D.

When pure semiconductor materials are used with no dopant added, the result is known as an "intrinsic semiconductor." When dopant is added, the material is known as an "extrinsic semiconductor."

Intrinsic and extrinsic materials have opposite thermal conductivity characteristics. An intrinsic material has a negative "temperature coefficient." That is, the resistance goes down as the temperature is increased. Extrinsic semiconductors have opposite behavior. Resistance goes up as heat goes up.

ACTIVITY SHEET

C 1.2

1. Devices which are made from semiconductor materials are often referred to as ______________________ devices.

2. The two semiconductor materials most commonly used to manufacture electronic components are ______________________ and ________________________.

3. The resistance of a semiconductor, when compared to copper is ______________.

   A. Higher
   B. Lower
   C. About the same

4. The outermost shell of an atom is called the ______________________ shell.

5. The current carriers in conductors are ____________________ electrons.

6. Elements which are made up of atoms with four electrons in their outermost shells are called ________________________.

7. Intrinsic semiconductors do not contain __________________.

8. Extrinsic semiconductors have a ________ temperature coefficient.

9. An electron has a ________________ charge.

10. Holes move in the same direction as the electrons.

    A. True
    B. False

11. A hole has a ____________________ charge.

510

ACTIVITY SHEET KEY C 1.2

1. Solid State
2. Germanium and Silicon
3. A
4. Valence
5. Valence
6. Semiconductors
7. Impurities
8. Positive
9. Negative
10. B
11. Positive

INFORMATION SHEET

C 1.3

GERMANIUM AND SILICON ATOMS

To create more electrons and holes, which results in the ability to conduct more current, semiconductors go through a process known as "doping." Doping is the process in which an impurity is added to the semiconductor. Two types of impurities are added to silicon and germanium. One type of impurity is referred to as a "pentavalent" material because its atoms have five valence electrons. The other type is referred to as a "trivalent" material because its atoms have three valence electrons.

The most widely used pentavalent material today is arsenic. When arsenic is added to silicon or germanium, the result is a material referred to as an N-type; the majority carrier is electrons; the holes are minority carriers. Refer to Figure C 1.3-1.

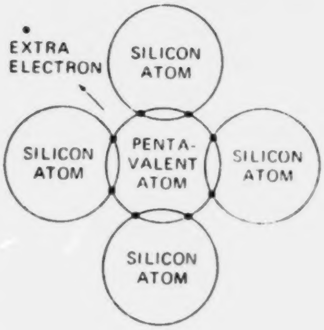

EXTRA ELECTRON
SILICON ATOM
SILICON ATOM
PENTA-VALENT ATOM
SILICON ATOM
SILICON ATOM

Figure C 1.3-1

The most widely used trivalent material is gallium. When gallium is added to silicon or germanium, the result is a material referred to as P-type; the majority carrier is holes and the minority carrier is electrons. Refer to Figure C 1.3-2.

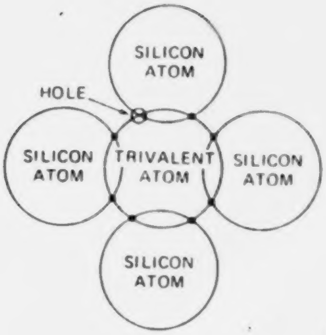

SILICON ATOM
HOLE
SILICON ATOM
TRIVALENT ATOM
SILICON ATOM
SILICON ATOM

Figure C 1.3-2

ACTIVITY SHEET

C 1.4

1. A semiconductor can be made a better conductor by a process called ________________________________.

2. For the N-type semiconductor, the majority carriers are ____________________.

3. An impurity that has five valence electrons is called a ___________________ material.

4. Semiconductor materials with electrons as majority carriers are known as _________________________ type.

5. An impurity that has three valence electrons is called a ______________________ material.

6. Semiconductor materials with holes as majority carriers are known as _______________________ type.

7. With increased doping, the resistance of a semiconductor ____________________.

513

ACTIVITY SHEET KEY C 1.4

1. Doping
2. Electrons
3. Pentavalent
4. N
5. Trivalent
6. P
7. Decreases

INFORMATION SHEET

C 1.5

DIODE BIASING

Now that you have examined the properties of semiconductor materials, we will begin a study of the various semiconductor components used in solid state, the first one being the "diode."

A semiconductor diode is formed by joining N- and P-type semiconductors at a junction. This diode is called a "junction "diode" (Figure C 1.5-1). Referring to Figure C 1.5-2, electrons and positive holes combine at the junction point, with the free electrons from the N-type moving to the P side of the diode. The holes in the P-type will now be filled. This action at the junction point extends a very short distance. The region is known as the "depletion layer", as noted in Figure C 1.5-2.

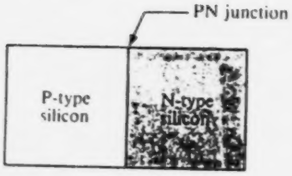


Figure C 1.5-1

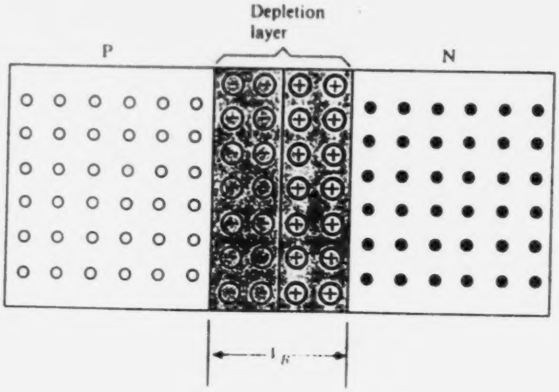


Figure C 1.5-2

The depletion action cannot go on forever. The reversal of these charges ends in a short time. The depletion action ceases because each side accumulates enough charges to repel opposing charges. On the P side, there is a negative charge between two positive areas. The same thing happens on the negative side; this creates a potential barrier, or "barrier voltage." This barrier indicates that the drift has stopped; this limits the size of the depletion region within the diode.

The barrier voltage is a very small voltage. For germanium diodes, the barrier voltage is .3 volts. For silicon diodes, the barrier voltage is .7 volts.

For Figure C 1.5-3, a PN junction diode is connected to an external voltage in such a way that the depletion region is collapsed. The positive holes on the P-type side will be pushed to the junction. This causes the depletion region to collapse. Under this condition the diode is said to be forward biased. "Forward bias" is the condition that exists when the Diode is said to be "turned on."

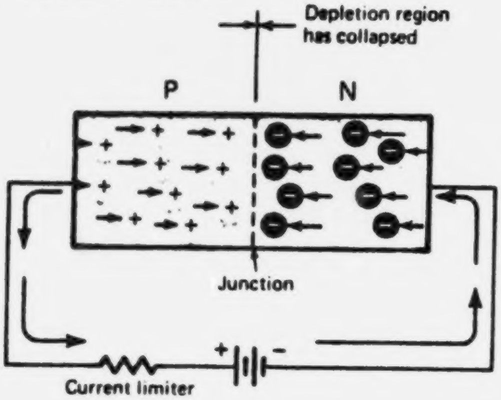

Depletion region
has collapsed
P
N
Junction
+
-
Current limiter

Figure C 1.5-3

"Reverse bias" occurs under the opposite condition and is shown in Figure C 1.5-4. Since N-type material has a few minority holes and P-type material has a few minority electrons, this will result in a small leakage current (Figure C 1.5-5).

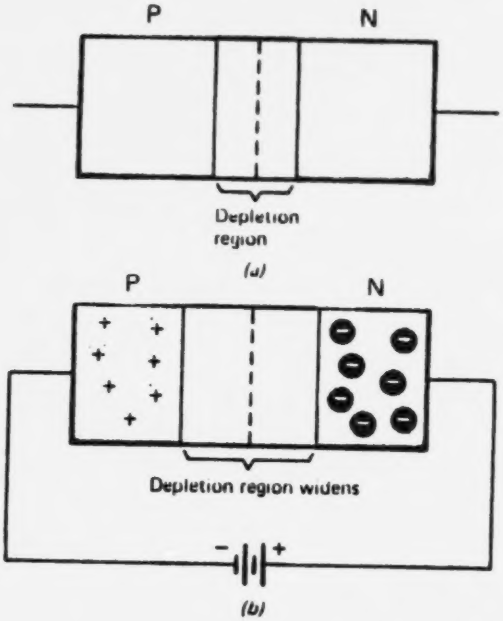

P
N
Depletion
region
(a)
P
N
Depletion region widens
-
+
(b)

Figure C 1.5-4

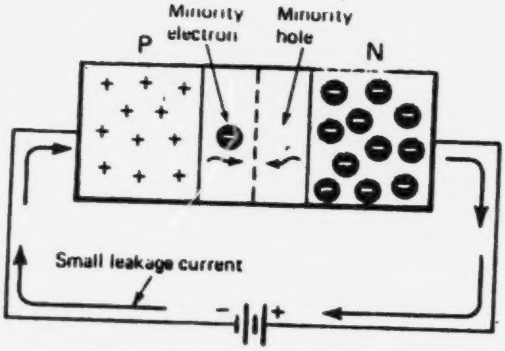

Minority
electron
Minority
hole
P
N
Small leakage current
-
+

Figure C 1.5-5

ACTIVITY SHEET

C 1.6

1. The voltage across a conducting silicon diode will be ___________ volts.

2. A diode is formed by joining ______________ semiconductor material and __________________ semiconductor material.

3. The opposite charges that build up at the PN junction create a potential that is known as the __________________.

4. A reverse-biased diode has ___________ current flow.

5. The depletion region disappears when the diode is _________________.

6. A diode is said to be __________ when it is forward-biased.

7. The voltage drop across a conducting germanium diode will be ___________________ volts.

8. For a diode to be forward-biased, the negative terminal of the battery must be connected to the ______________ section of the diode.

9. To cause current to flow in a forward-biased diode, the external voltage must exceed the ___________________.

10. When a diode is reversal-biased, its depletion region is ________________ than when unbiased.

ACTIVITY SHEET KEY C 1.6

1. .7
2. N-type and P-type
3. Barrier voltage
4. Minority
5. Forward-Biased
6. turned-on
7. .3
8. N
9. Barrier Potential
10. Expanded or widened

INFORMATION SHEET

C 1.7

SEMICONDUCTOR DIODE CHARACTERISTICS

One of the most important characteristics of the diode is that it conducts well in one direction, but not in the other. The diode has two important ratings, the amount of current it can safely conduct, and the amount of "PIV" (Peak Inverse Voltage). The PIV is the rating at which point the barrier voltage breaks down and the reverse current becomes excessive. Figure C 1.7-1 represents this condition.

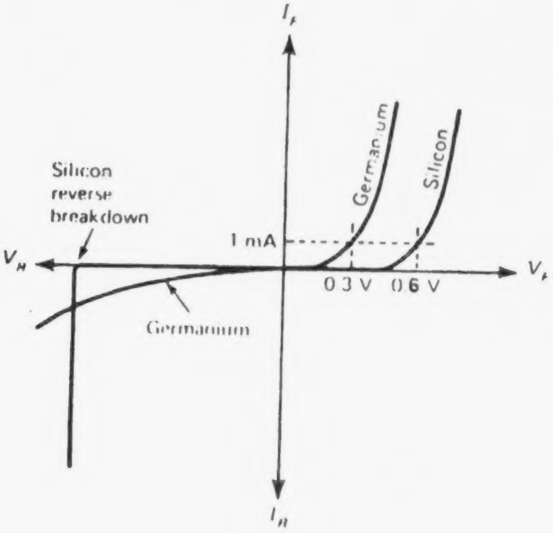


Figure C 1.7-1

The germanium diode shows more leakage current, but the silicon diode shows a rapid increase in reverse current at one point. This point is called "breakdown voltage" or "avalanche voltage," and is called PIV.

Temperature affects the operation of a diode. In general, the effect is the opposite of the temperature change; that is, the lower the temperature, the better the diode operates. A study of Figure C 1.7-2 will help to show you these effects.

INFORMATION SHEET C 1.7 CONT'D.

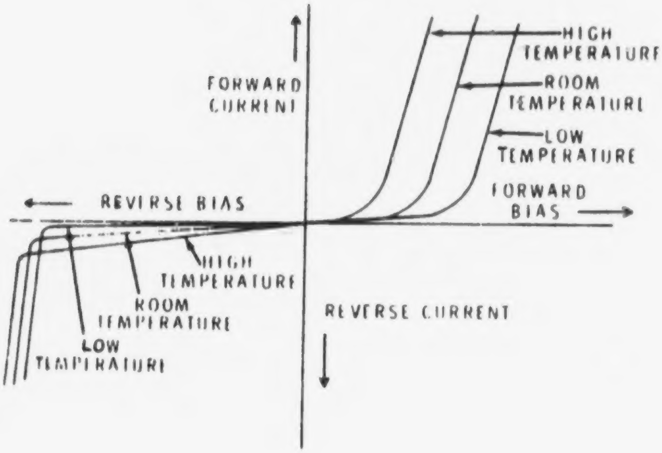


Figure C 1.7-2

The diode "symbol" is shown in Figure C 1.7-3. Figure C 1.7-4 shows the diode symbol along with several diode packages. Study both until you are familiar with the symbol and these packages.

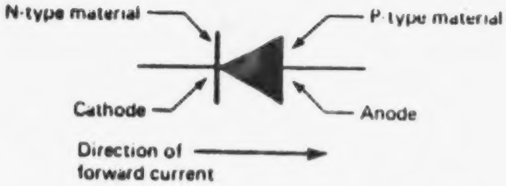

N-type material
P-type material
Cathode
Anode
Direction of forward current

Figure C 1.7-3

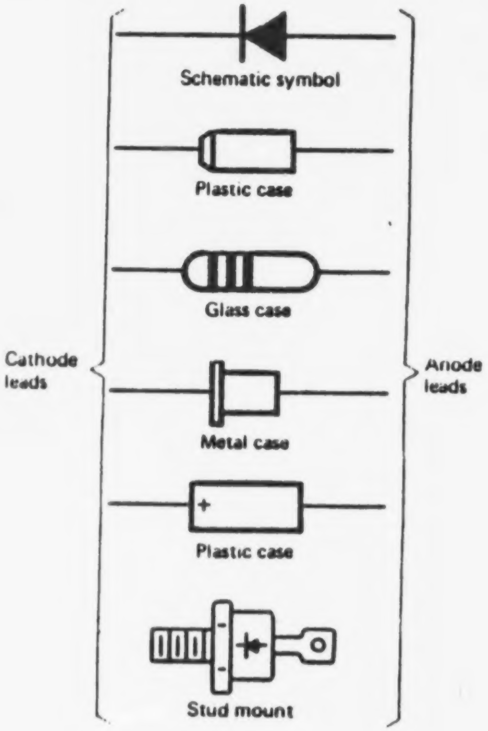

Schematic symbol
Plastic case
Glass case
Cathode leads
Anode leads
Metal case
Plastic case
Stud mount

Figure C 1.7-4

ACTIVITY SHEET

C 1.8

1. If the temperature of a diode increases, the voltage drop across it will ____________________.

2. The P section of a diode is represented by the ________________ in the symbol.

3. Both germanium and silicon diodes can be damaged by excessively high reverse ______________________.

4. The abbreviation PIV stands for ______________ ___________ ______________.

5. Under normal conditions the voltage drop across a silicon diode will be ___________ than a germanium diode.

   A. Higher
   B. Lower

6. A drastic increase in reverse current occurs when the ______________________ occurs.

7. The N section of a diode is represented by the ___________ in the diode symbol.

8. For a stud-mount diode the bolt end is the ______________ of the diode.

9. For a plastic-case diode the unmarked end is the _________________ of the diode.

10. Diode avalanche or reverse breakdown, is caused by excess reverse ______________________.

ACTIVITY SHEET KEY C 1.8

1. Increase
2. Triangle or arrow
3. Voltage
4. Peak Inverse Voltage
5. A
6. Breakdown
7. Straight Line
8. Cathode
9. Anode
10. Voltage

PROGRAM: ELECTRONICS

TASK: SEMICONDUCTOR DIODES

TASK # C 1.9

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ______________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

PERFORMANCE OBJECTIVE:

Identify the properties of semiconductor materials and explore semiconductor diodes.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and you must score at least 80 out of 100 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 80 out of 100 points or 80%, and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

SEMICONDUCTOR DIODES

C 1.9

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
1.	Does circuit function correctly?	Y	N
*2.	Was circuit wired according to schematic?	Y	N
3.	Are connections correct?	Y	N
4.	Was necessary data recorded?	Y	N
*5.	Was correct equipment used?	Y	N
*6.	Was equipment used properly?	Y	N
*7.	Were safety precautions followed?	Y	N
8.	Was equipment returned to proper storage?	Y	N

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

SCORE _____

SEMICONDUCTOR MATERIALS AND DIODES

EXAM C 1.10

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on the semiconductor materials and diodes. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, or C) in the numbered blank space on your answer sheet. Do not write on this test!!! To master this exam you must answer 16 out of 20 items correctly.

EXAM C 1.10

1. When compared to copper, the resistance of semiconductor materials will be ____________.

   A. Higher
   B. Lower
   C. About the same

2. The most widely used semiconductor materials today are germanium and silicon.

   A. True
   B. False

3. Holes have a ____________ value .

   A. Negative
   B. Positive
   C. No charge

4. Electrons move in the ______________ direction as holes.

   A. Same
   B. Opposite

5. When the majority carrier is holes, the material is known as _____________ type.

   A. P
   B. N
   C. PN

6. The process which makes a semiconductor a better conductor is called ____________.

   A. Depletion
   B. Junctions
   C. Doping

7. With increased doping the resistance of a semiconductor will be _____________:

   A. Higher
   B. Lower
   C. Same

EXAM C 1.10 CONT'D.

8. In N-type material the majority carrier will be ___________.

   A. Electrons
   B. Holes
   C. Ions

9. Two semiconductor materials are used to form a diode; they are silicon and arsenic.

   A. True
   B. False

10. A forward-biased diode acts the same as a switch that is ___________.

   A. Open
   B. Closed
   C. Neither

11. When a diode is reverse biased the depletion region gets ___________.

   A. Larger
   B. Smaller

12. The current that flows in a reverse-biased diode is called ___________.

   A. Leakage
   B. Majority
   C. Minority Current

13. The voltage drop across a conducting silicon diode will be ___________.

   A. .7
   B. .3
   C. 1.0

14. When the negative terminal of the battery is connected to the N-type material the diode is said to be ____________.

   A. Reverse
   B. Positive
   C. Forward

15. If the voltage drop across a conducting diode is .3 volt, the diode will be a _______________ diode.

    A. Silicon
    B. Arsenic
    C. Germanium

16. To cause current to flow in any diode, the voltage drop across it must exceed the _______________.

    A. Reverse Bias
    B. Barrier Potential
    C. Minority Carrier

17. In the diode symbol, the P-type section is represented by the __________________.

    A. Triangle or arrow
    B. Band
    C. Short lead

18. The amount of reverse bias a diode can stand is called the __________________.

    A. Forward bias
    B. Reverse bias
    C. PIV

19. If you increase the temperature of a diode, the voltage drop across it will __________________.

    A. Decrease
    B. Increase
    C. Stay the same

20. The unmarked end of a plastic-case diode is referred to as the _______________.

    A. Anode
    B. Cathode
    C. PIV

EXAM KEY C 1.10

1. A
2. A
3. B
4. B
5. A
6. C
7. B
8. A
9. B
10. B
11. A
12. A
13. A
14. C
15. C
16. B
17. A
18. C
19. B
20. A

ELECTRONICS

ANALYZING SOLID STATE DEVICES

C 2: ZENER AND OTHER DIODE CHARACTERISTICS

TASK: Examine zener diode characteristics and other diodes.

PURPOSE: The zener diode is an extremely important component to the electronic industry. You must become familiar with this device and its operation. We will also study other special purpose diodes.

OBJECTIVE: Given the necessary information on the characteristics of the zener diode and its operation, as well as other special purpose diodes, you will master this task, scoring at least 80% on written exams and laboratory performance.

ESTIMATED CLASS TIME: 6 HOURS

THE ZENER DIODE AND OTHERS

LEARNING STEPS

C 2

READ: Information Sheet C 2.1, "Characteristics of the Zener Diode."

READ: Information on characteristics of the zener diode from the following resource list.

COMPLETE: Activity Sheet C 2.2, "Characteristics of the Zener Diode."

READ: Information Sheet C 2.3, "Special Application Diodes--The Varactor Diode."

READ: Information on the varactor diode from the following resource list.

COMPLETE: Activity Sheet C 2.4, "Varactor Diode."

READ: Information Sheet C 2.5, "Tunnel Diodes and Other High Frequency Diodes."

READ: Information on the tunnel diode and other high-frequency diodes.

COMPLETE: Activity Sheet C 2.6, "Tunnel Diodes and Other High-Frequency Diodes."

COMPLETE: Lab Performance on zener diode characteristics and other diodes. Contact your instructor.

COMPLETE: Lab Performance Checklist C 2.7. Contact your instructor.

COMPLETE: Exam C 2.8.

THE ZENER DIODE AND OTHER DIODES

RESOURCES

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1985). Fifth Edition.
2. Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). Fifth Edition.
3. Badrkhan and Lark, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984).
4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS (McGraw-Hill, 1984). Second Edition.
5. SEMICONDUCTOR DEVICES (Heath Company, 1982). Eighteenth Printing.

RECOMMENDED EQUIPMENT

0-24 VDC power supply
Volt-OHM meter or digital multimeter
Various zener diodes
Other diodes, as supplied by instructor

INFORMATION SHEET

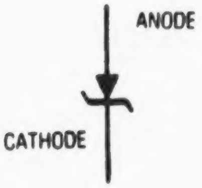
C 2.1

CHARACTERISTICS OF THE ZENER DIODE

Ordinary junction diodes are considered to be malfunctioning and in danger of being damaged when reverse-breakdown voltage is reached.

However, a special diode is made to take advantage of this breakdown point to deliver a constant reliable voltage source. This diode is known as the "zener diode." The symbol for the zener diode is shown in Figure C 2.1-1. To help understand the zener operation, study Figure C 2.1-2. This shows how the zener is designed to operate at a specified reverse-breakdown voltage. A typical circuit using the zener diode as a regulator is shown in Figure C 2.1-3.

Figure C 2.1-1



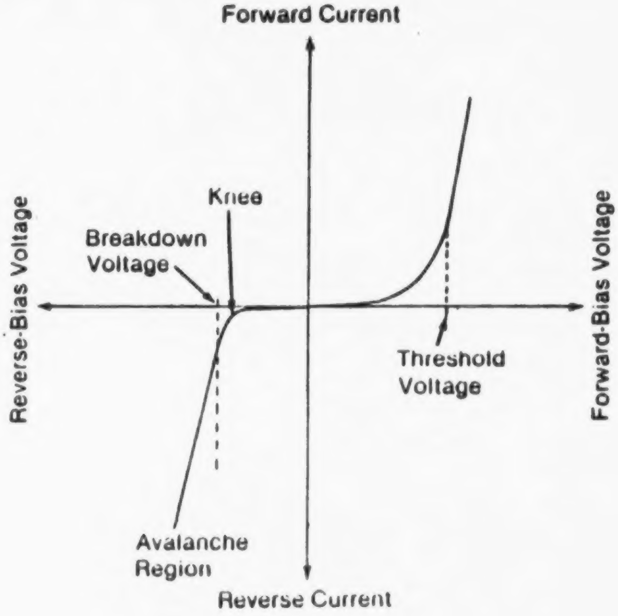


Figure C 2.1-2

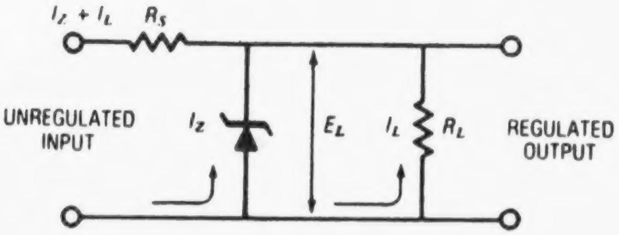


Figure C 2.1-3

INFORMATION SHEET C 2.1 CONT'D.

The zener has some special characteristics: zener current, zener voltage, and operating temperature. The zener current is important because, if it goes too high, the device will exceed its power rating and become damaged by heat. The zener voltage is important in that there is no zener action if it is too low. If it exceeds its voltage rating, it will be damaged by excessive zener current.

The third zener characteristic which must be considered is the temperature. This is a result of the amount of power the device can safely dissipate. A better understanding of the relationship between the temperature and power rating of a zener is shown in Figure C 2.1-4. To help with the temperature effect, some zeners are temperature-compensated. This is accomplished by hooking an ordinary PN junction diode in series with the zener.

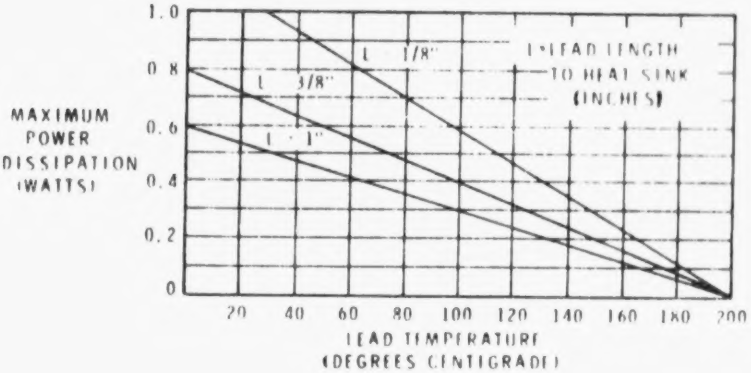


Figure C 2.1-4

ACTIVITY SHEET

C 2.2

1. A zener diode used as a shunt regulator will be connected in ____________________ with the load.

2. When used as a voltage regulator the zener diode must be ________________________ biased.

3. If a manufacturer rates a zener at 10 volts with a 10% tolerance, this means the zener voltage lies between ____________________ V and _________________ V.

4. The maximum safe reverse current that a zener can handle can be calculated by dividing the diode's power rating by its ______________ _______________.

5. One of the ratings of a zener will be the maximum ___________ current that can flow before breakdown.

6. A power supply develops 8 volts; for a regulated 5- volt output with 500 milliamperes, the value of the limiting resistor should be __________________ ohms.

ACTIVITY SHEET KEY C 2.2

1. Parallel
2. Reverse
3. 9 and 11
4. Zener voltage
5. Reverse
6. 5.45

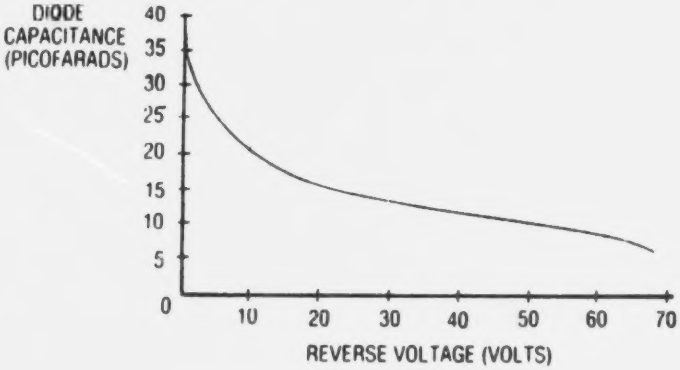
INFORMATION SHEET

C 2.3

SPECIAL APPLICATION DIODE--THE VARACTOR DIODE

When any PN-junction diode is reverse biased, a wide depletion region is formed at the diode's junction, since the region is an insulator and can be varied by controlling the amount of the applied reverse bias. As you know from previous studies, when two conductors are separated by a dielectric, you have a component known as a "capacitor." Electrically the reverse-biased diode acts as a small capacitor. A diode constructed with this in mind is called a varactor diode. The diode's capacitance will vary inversely with the applied voltage. By referring to Figure C 2.3-1 you can see that this is a nonlinear charge.

Figure C 2.3-1



Varactors are constructed in a variety of sizes and shapes and have various power, current and voltage ratings. They are also constructed with many different capacitance values.

The varactor's principal use is in tuning circuits, as a tuning capacitor. The various symbols for the varactor are noted in Figure C 2.3-2.

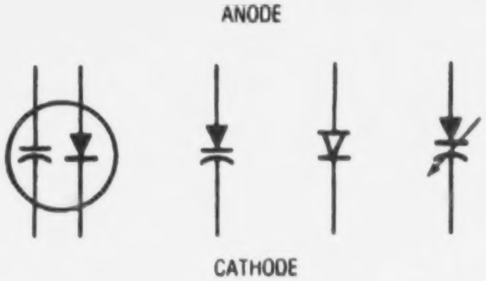


Figure C 2.3-2

ACTIVITY SHEET

C 2.4

1. If the reverse bias across a varactor is increased, the internal capacitance will ________________.

2. The desired leakage current in a varactor should be ________________________.

3. A varactor is usually operated with its reverse bias lower than its ___________________voltage.

4. Most varactors are made from _________________.

5. The Q of a varactor is normally a ______________ number.

6. The varactor is often used as a ______________ component in a tuning circuit.

ACTIVITY SHEET KEY C 2.4

1. Increase
2. Low
3. Breakdown
4. Silicon
5. Low
6. Capacitor

INFORMATION SHEET

C 2.5

TUNNEL DIODES AND OTHER HIGH-FREQUENCY DIODES

The device known as a "tunnel diode" differs notably from the ordinary diode. Tunnel diodes are heavily doped, resulting in a narrow depletion and a low reverse breakdown voltage. With this type of construction and a low forward bias, electrons flow through the diode at extremely high velocity. The characteristic gives the diode its name; the electrons appear to "tunnel" through the junction.

The symbol used to represent the tunnel diode is shown in Figure C 2.5-1, and the operating characteristics are shown in Figure C 2.5-2.

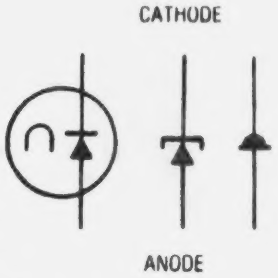


Figure C 2.5-1

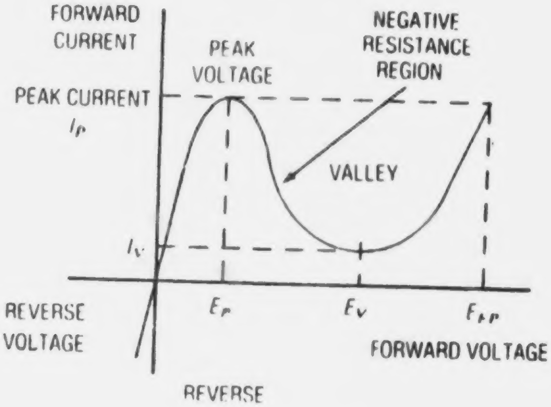


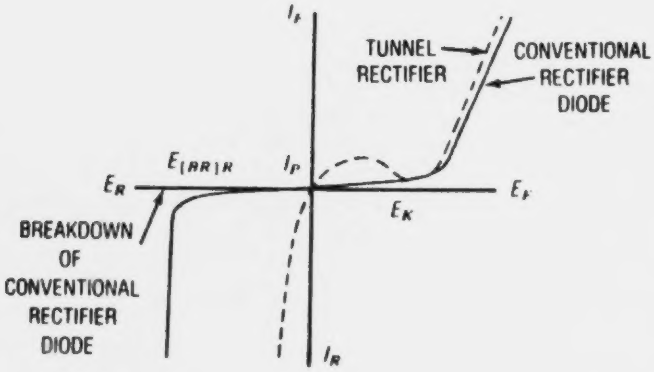
Figure C 2.5-2

From its construction the diode has a unique characteristic of "negative resistance." This condition occurs when, at a point, an increase in forward-bias voltage causes a decrease in forward current. This creates a unique characteristic known as "valley current" and "valley voltage."

Tunnel diodes are used mainly as oscillators in various generators. If the level of doping is lowered, a device will be developed with excellent high-frequency response. This is the "tunnel rectifier" or "back diode."

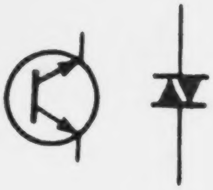
With the lowering of the dopant the peak-to-valley ratio becomes extremely low, as is noted in Figure C 2.5-3. The symbol for the tunnel rectifier is the same as a tunnel diode. Tunnel rectifiers are used in many high frequency applications.

Figure C 2.5-3



Another specially constructed diode is the "diac" (see Figure C 2.5-4). The diac can be used as a "trigger diode" or "bidirectional trigger diode." It is used as an electronic switch.

Figure C 2.5-4



Symbols

Another diode can be constructed by placing N-type material in contact with a metallic P-type material. This results in a diode with a barrier voltage of approximately .3V. Since the characteristic of this diode is similar to the diode tube, it is called the "hot-carrier diode." These diodes can turn off and on at a rapid rate. The symbol for the hot-carrier diode is shown in Figure C 2.5-5. It is sometimes called the "schottky diode."

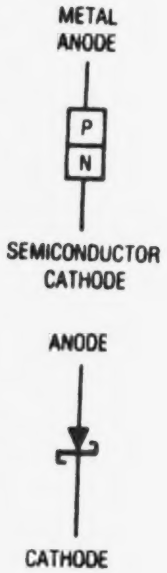

METAL
ANODE
P
N
SEMICONDUCTOR
CATHODE
ANODE
CATHODE

Figure C 2.5-5

A "pin diode" is, in effect, a solid state resistor for which the resistance can be varied by the amount of current applied. The end result is an electronic variable resistor.

The device is constructed as shown in Figure C 2.5-6. The time this device takes to operate is such that it cannot serve as a rectifier at microwave frequencies. Since it is not a rectifier, it becomes a variable alternator controlled by a DC bias current.

Two other diodes you need to become familiar with are the "impatt" diode and the "gunn-effect" diode. These diodes, unlike other diodes, are used to generate radio frequency (RF) energy in the microwave range. These are covered in the resource books listed in the Learning Steps in this learning guide.

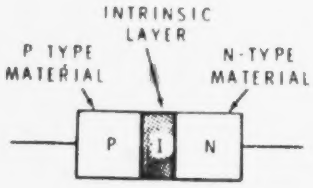

INTRINSIC
LAYER
P TYPE
MATERIAL
N-TYPE
MATERIAL
P
I
N

Figure C 2.5-6

ACTIVITY SHEET

C 2.6

1. The negative resistance region occurs when the tunnel diode is ____________________ biased.

2. The principal use of the tunnel diode is as a _____________.

3. When operating in the negative resistance region, the forward current __________________ as the forward voltage increases.

   A. Increases
   B. Decreases

4. When used as an oscillator, the tunnel diode is biased to operate within its _________________ _______________ region.

5. The tunnel rectifier has ______________ dopant when compared to the tunnel diode.

6. The peak-to-valley ratio of the tunnel diode is ____________ when compared to the tunnel rectifier.

7. A 12-V zener diode has a maximum reverse current rating of 500 milliamperes. The lowest power rating of the diode should be 5 watts.

   A. True
   B. False

ACTIVITY SHEET KEY C 2.6

1. Forward
2. Oscillator
3. B
4. Negative resistance
5. Less
6. High
7. B

PROGRAM: ELECTRONICS

TASK: ZENER DIODE AND OTHER DIODE CHARACTERISTICS

TASK # C 2.7

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

PERFORMANCE OBJECTIVE:

Examine zener diode characteristics and other diodes.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 80 out of 100 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 80 out of 100 points or 80% and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

ZENER DIODE AND OTHER DIODE CHARACTERISTICS

C 2.7

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
1.	Does circuit function correctly?	Y	N
*2.	Was circuit wired according to schematic?	Y	N
3.	Are connections correct?	Y	N
4.	Was necessary data recorded?	Y	N
*5.	Was correct equipment used?	Y	N
*6.	Was equipment used properly?	Y	N
*7.	Were safety precautions followed?	Y	N
8.	Was equipment returned to proper storage?	Y	N

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

SCORE _____

ZENER DIODE AND OTHER DIODE CHARACTERISTICS

EXAM C 2.8

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on zener diode characteristics and other diodes. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. Do not write on this test!! To master this exam you must answer 12 out of 15 items correctly, OR 80%.

THE ZENER DIODE AND OTHER DIODE CHARACTERISTICS

EXAM

C 2

1. The zener diode must be ________________ biased.

   A. Forward
   B. Reverse

2. The ideal zener diode would have a zener impedance of ______________ ohms.

   A. .3
   B. .7
   C. 0
   D. 3

3. When using a zener as a shunt regulator, it will be connected in ____________________ with the load.

   A. Series
   B. Parallel

4. Zener diodes which have axial leads will be ______________ power zener diodes.

   A. Low
   B. High
   C. Extremely high

5. If a zener diode is rated at 20 volts, plus or minus 10%, the zener voltage lies between _______ and _______ volts.

   A. 18 and 20
   B. 19 and 21
   C. 18 and 22
   D. 20 and 22

6. To function as a voltage regulator, a zener diode must have input DC voltage greater than its breakdown voltage.

   A. True
   B. False

7. Operating the zener diode in the breakdown voltage/avalanche current area will cause structural damage to the diode.

   A. True
   B. False

EXAM C 2.8 CONT'D.

8. The zener diode is designed to operate over a wide range of current values and maintain a relatively constant voltage across the diode.

   A. True
   B. False

9. The varactor diode will act as a capacitor with forward or reverse bias applied.

   A. True
   B. False

10. The dielectric of the varactor diode is in the junction depletion area.

   A. True
   B. False

11. The greatest change in capacitance in the varactor diode is when the reverse bias is ________________.

   A. Low
   B. High
   C. The same

12. The doping of a tunnel diode is lighter than that of a conventional diode.

   A. True
   B. False

13. The varactor diode is most used as an amplifier.

   A. True
   B. False

14. The negative resistance of a device is the area when an increase in forward voltage causes an increase in the forward current.

   A. True
   B. False

15. The peak to valley ratio of a tunnel rectifier is higher than the peak to valley ratio of a tunnel diode.

   A. True
   B. False

EXAM KEY C 2.8

1. B
2. C
3. B
4. A
5. C
6. A
7. B
8. A
9. B
10. A
11. B
12. B
13. B
14. B
15. B

ELECTRONICS

ANALYZING SOLID STATE DEVICES

C 3: BIPOLAR-TRANSISTOR CHARACTERISTICS

TASK:	Examine bipolar-transistor characteristics.
PURPOSE:	The transistor is a solid state device that is rapidly becoming the most common of all components used in the electronics field. Since the bipolar transistor is the most common of all transistors, it is essential that you understand this device.
OBJECTIVE:	Given the necessary information on bipolar transistor characteristics, and the operation of these devices, you will master this task and score at least 80% on written exams and laboratory performance.

ESTIMATED CLASS TIME: 6 HOURS

BIPOLAR TRANSISTOR CHARACTERISTICS

LEARNING STEPS

C 3

READ:	Information Sheet C 3.1, "Bipolar Transistor Construction."
READ:	Information on bipolar transistor construction from the following resource list.
COMPLETE:	Activity Sheet C 3.2, "Bipolar Transistor Construction."
READ:	Information Sheet C 3.3, "Biasing the Bipolar Transistor."
READ:	Information on biasing the bipolar transistor from the following resource list.
COMPLETE:	Activity Sheet C 3.4, "Biasing the Bipolar Transistor."
READ:	Information Sheet C 3.5, "Bipolar Transistor Amplification."
READ:	Information on bipolar transistor amplification from the following resource list.
COMPLETE:	Activity Sheet C 3.6, "Bipolar Transistor Amplification."
COMPLETE:	Lab Performance on bipolar transistor characteristics. Contact your instructor.
COMPLETE:	Performance Checklist C 3.7. Contact your instructor.
COMPLETE:	Exam C 3.8.

BIPOLAR TRANSISTOR CHARACTERISTICS

RESOURCES

C 3

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1985). Fifth Edition.
2. Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). Fifth Edition.
3. Badrkhan and Larky, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984).
4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS (McGraw-Hill, 1984). Second Edition.
5. SEMICONDUCTOR DEVICES (Heath Company, 1982). Eighteenth Printing.

RECOMMENDED EQUIPMENT

0-20 VDC power supply
Various transistors
Dual-trace oscilloscope

INFORMATION SHEET

C 3.1

BIPOLAR TRANSISTOR CONSTRUCTION

As you know from previous studies, all PN diodes are two-element semiconductor devices. They are produced by placing P-type and N-type materials together. Where these two materials join each other, a thin area develops. This area is referred to as the "PN junction." With the proper bias applied, the device permits the flow of current in one direction, but not the other.

Transistors are three-element devices. They are produced by placing a P-type or N-type material between two sections of the other type of material. A PNP transistor is formed when N-type material is placed between 2 P-type materials. An NPN transistor is formed when P-type material is placed between two N-type materials. This type of construction forms two PN Junctions. Therefore, these devices are frequently referred to as "bipolar" devices. Refer to Figure C 3.1-1 and 3.1-2 for the construction and symbols of these devices.

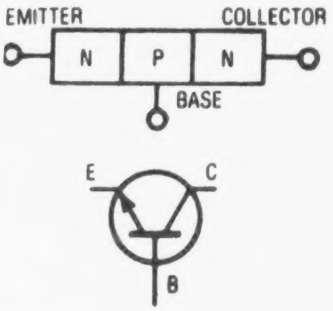


Figure C 3.1-1

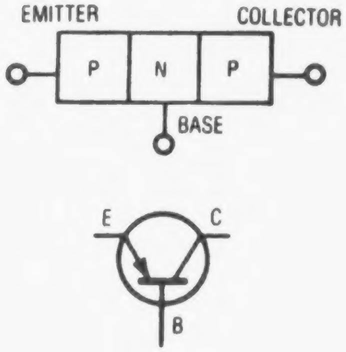


Figure C 3.1-2

For the bipolar transistor the three elements are called the emitter, base, and collector. One PN junction is the emitter-base, or emitter junction, between the emitter and base. The other PN junction is the collector-base, CB, or collector junction. If the EB junction is forward biased and CB junction is reverse biased, current will flow through the transistor. If this junction voltage is varied, the current flow through the device will vary also.

INFORMATION SHEET C 3.1 CONT'D.

Transistors are manufactured in several types of cases depending on current and power requirements; see Figure C 3.1-3 for samples of common transistor cases.

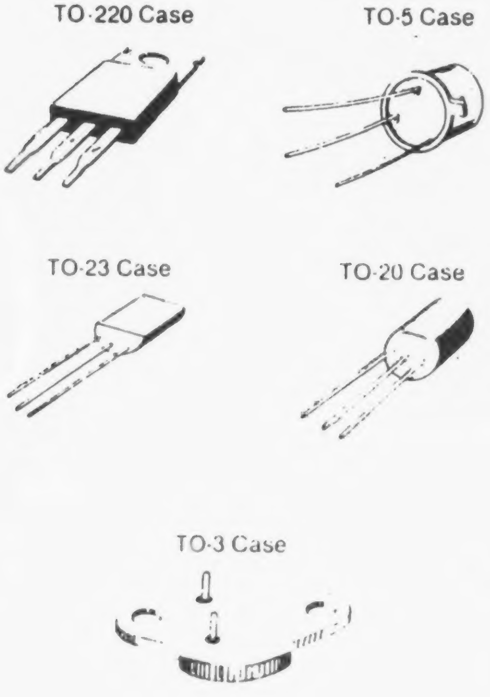

TO-220 Case
TO-5 Case
TO-23 Case
TO-20 Case
TO-3 Case

Figure C 3.1-3

ACTIVITY SHEET

C 3.2

1. If a bipolar transistor has an N-type material sandwiched between two P-type materials, it is referred to as a ________________ transistor.

2. Bipolar transistors have only one PN junction.

   A. True
   B. False

3. Transistors are ____________________ element devices.

4. Bipolar transistors are formed by simply pressing sections of N-type and P-type materials together.

   A. True
   B. False

5. The three elements of a transistor are the ________________, ____________________ and ____________________.

6. The EB junction of a transistor is normally ________________ biased with a _______________ voltage.

7. If a bipolar transistor has a P-type sandwiched between two N-type sections, it is referred to as a(n) ________________ transistor.

   A. PNP
   B. NPN

8. The CB junction of a transistor is normally ________________ biased with a ________________ voltage.

9. The most important uses for transistors are as ____________.

   A. Amplifiers
   B. Rectifiers

ACTIVITY SHEET KEY C 3.2

1. PNP
2. B
3. Three
4. B
5. Emitter, base, and collector
6. Forward, small
7. B
8. Reverse, large
9. A

INFORMATION SHEET

C 3.3

BIPOLAR TRANSISTOR BIASING

The primary and most important function of the bipolar transistor is to provide amplification. To perform this task the transistor must be properly biased. Since the transistor has two PN junctions, the biasing techniques will be more complex than those of the diode with one PN junction.

As you know from previous studies, the emitter junction must be forward biased and the collector junction reverse biased for correct operation. This is shown schematically in Figure C 3.3-1 and C 3.3-2. A study should be made of these two figures to familiarize yourself with the current flow in these two junctions.

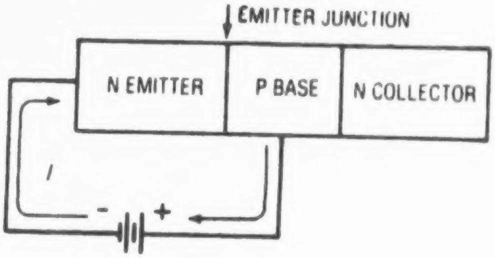

EMITTER JUNCTION
N EMITTER
P BASE
N COLLECTOR
I
-
+

Figure C 3.3-1

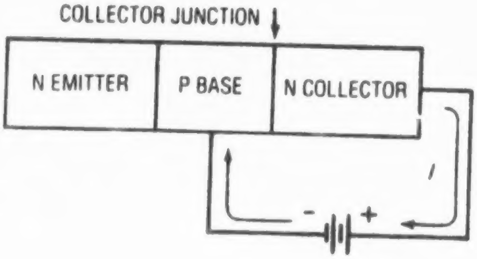

COLLECTOR JUNCTION
N EMITTER
P BASE
N COLLECTOR
I
-
+

Figure C 3.3-2

The current flow of a properly biased NPN bipolar transistor is shown in Figure C 3.3-3. A PNP transistor with proper bias is shown in Figure C 3.3-4. To determine the emitter current, base current, and collector current, use the following formulas: $I_e = I_b + I_c$; $I_c = I_e - I_b$; $I_b = I_e - I_c$. These formulas apply to both PNP and NPN, although the voltage for the NPN will be opposite the polarity for a PNP.

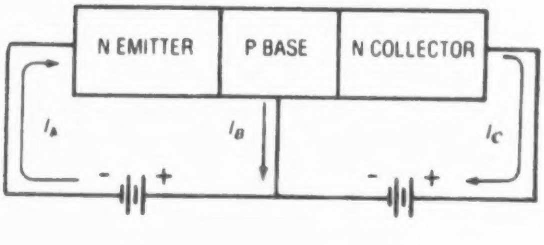

N EMITTER
P BASE
N COLLECTOR
I_E
I_B
I_C
-
+
-
+

Figure C 3.3-3

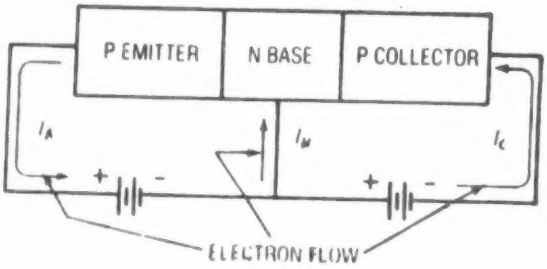

P EMITTER
N BASE
P COLLECTOR
I_E
I_B
I_C
+
-
+
-
ELECTRON FLOW

Figure C 3.3-4

INFORMATION SHEET C 3.3 CONT'D.

The bipolar transistor is never to be thought of as two diodes fixed back-to-back. The construction is different, both physically and electrically.

ACTIVITY SHEET

C 3.4

1. What is the most important application for the bipolar transistor?

2. How many junctions are in a bipolar transistor?

3. The base current of a transistor should be between ____________ and _____________ % of the emitter current.

4. The junction formed between the emitter and base is called the _________________ junction.

5. In a bipolar transistor, the magnitude of the I_e, I_b and I_c will be controlled by the ________________ _______________.

6. Complete the following formulas showing the relationship between I_e, I_b, and I_c.

   $I_e =$
   $I_b =$
   $I_c =$

7. If the forward-bias voltage at the emitter of a transistor is increased, the following currents also increase: I_e, I_b, and I_c.

   A. True
   B. False

8. The collector junction of a transistor is ____________.

   A. Reverse bias for PNP and forward bias for NPN
   B. Forward bias at all times
   C. Reverse bias at all times
   D. Reverse bias for NPN and forward bias for PNP

ACTIVITY SHEET KEY C 3.4

1. Amplification
2. Two
3. One and five
4. Emitter
5. Forward bias
6. $I_e = I_b + I_c$
   $I_b = I_e - I_c$
   $I_c = I_e - I_b$
7. A
8. C

INFORMATION SHEET

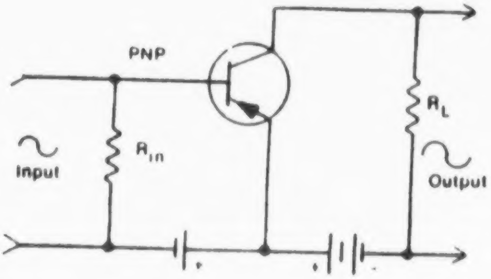
C 3.5

BIPOLAR TRANSISTOR AMPLIFICATION

From previous study you should have an understanding of how bias controls the current in the transistor. The most critical of the two junction voltages will be the emitter forward bias. A small change in emitter voltage causes a large change in the collector current.

Before we use the transistor, we must add a new component to the circuit. The component to be added, of course, is the "load resistor." This is shown in Figure C 3.5-1.

Figure C 3.5-1



From previous discussion on transistor action we saw that $I_e = I_b + I_c$ and we assumed that these currents were constant. However, by looking at the formula we can see that if one goes up, they all go up. When the forward bias on the emitter junction goes up, this increases I_e which, in turn, increases I_c. With the increase of I_c, the voltage drop across R^L increases.

With a decrease in the forward bias at the emitter junction, the opposite effect takes place. The end result is that the three currents tend to vary at the same percentage. When this takes place, the voltage drop across R^L will be varying in accordance with the forward bias at the emitter junction.

The emitter junction of the transistor is forward biased, and has a relatively low resistance. The collector junction is reverse biased and has a relatively high resistance. In spite of the big difference in the emitter junction resistance and the collector junction resistance, the collector current (I_c) is almost equal to the emitter current (I_e). This is due to the fact that only a very small portion of I_e flows out of the base region. The load resistor can therefore be a high value without restricting the value of I_c.

If a small signal is applied to the input terminals, this aids the forward bias, causing I_C to increase, along with the voltage drop across R_L. When the input signal is reversed, this opposes the forward bias, causing the voltage drop across R_L to decrease. The transistor now is made to take energy from an external power source and apply it to the load resistor as an output voltage controlled by a small input voltage. Although the transistor shown was a PNP, an NPN transistor will perform in the same manner.

Testing Transistors

Although the transistor is a solid state device and is capable of operating for a long period of time, it does occasionally become defective.

Transistor checkers are available; however, the ohmmeter is widely used to locate open and shorted transistors.

Refer to the resource material to understand the procedure for using the ohmmeter as a transistor checker.

ACTIVITY SHEET

C 3.6

1. The emitter, base, and collector currents in a bipolar transistor tend to vary by the same percentage.

   A. True
   B. False

2. An amplifier needs an input signal and a power supply to develop an output signal.

   A. True
   B. False

3. PNP and NPN transistor amplifiers have the same bias polarities.

   A. True
   B. False

4. The emitter region of a junction transistor has many current carriers.

   A. True
   B. False

5. The collector-base junction must be forward biased for proper transistor operation.

   A. True
   B. False

6. An NPN transistor and a PNP transistor can be interchanged.

   A. True
   B. False

7. The base of a transistor is heavily doped with impurities.

   A. True
   B. False

8. Negative-ground circuits favor the use of NPN transistors.

   A. True
   B. False

ACTIVITY SHEET C 3.6 CONT'D.

9. Base current controls collector current.

   A. True
   B. False

10. Base current is much greater than collector current.

   A. True
   B. False

ACTIVITY SHEET KEY C 3.6

1. A
2. A
3. B
4. A
5. B
6. B
7. B
8. A
9. A
10. B

PROGRAM: ELECTRONICS

TASK: BIPOLAR TRANSISTOR CHARACTERISTICS

TASK # C 3.7

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

PERFORMANCE OBJECTIVE:

Examine bipolar-transistor characteristics.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 80 out of 100 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 80 out of 100 points or 80%, and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

BIPOLAR TRANSISTOR CHARACTERISTICS

C 3.7

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Does circuit function correctly?	Y N
*2.	Was circuit wired according to schematic?	Y N
3.	Are connections correct?	Y N
4.	Was necessary data recorded?	Y N
*5.	Was correct equipment used?	Y N
*6.	Was equipment used properly?	Y N
*7.	Were safety precautions followed?	Y N
8.	Was equipment returned to proper storage?	Y N

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

SCORE _____

EXAM C 3.8

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on bipolar transistor characteristics. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on you answer sheet. Do not write on this test!!!! To master this exam you must answer 16 out of 20 items correctly, 80%.

EXAM C 3.8

1. If a bipolar transistor has an N-type material sandwiched between two P-type materials, it is called a ____________ transistor.

   A. Diode
   B. PNP
   C. NPN
   D. Power

2. The EB junction of a transistor is normally ____________ biased.

   A. Reverse
   B. Forward
   C. Zero
   D. Voltage

3. When compared to the collector voltage, the emitter voltage is _________.

   A. Identical
   B. Lower
   C. Higher
   D. Opposite

4. Bipolar transistors have ______________ PN junction(s).

   A. One
   B. Two
   C. Three
   D. Four

5. The CB junction of a bipolar transistor is _____________ biased.

   A. Neutral
   B. Forward
   C. Reverse
   D. Zero

6. The bipolar transistor has ________ number of elements.

   A. One
   B. Two
   C. Three
   D. Four

EXAM C 3.8 CONT'D.

7. The base current of a bipolar transistor should be between __________ and ______________ percent of the collector current.

   A. One and Five
   B. One and Ten
   C. Five and Ten
   D. Ten and Fifteen

8. The junction between the base and emitter is called the ___________ junction.

   A. Base
   B. Emitter
   C. Base-Emitter
   D. Emitter-Base

9. The formula for the total emitter current is _____________:

   A. $I_e = I_c - I_b$
   B. $I_e = I_b - I_c$
   C. I_e = Twice I_c
   D. $I_e = I_c + I_b$

10. The formula for the total base current is ________________:

   A. $I_b = I_e + I_c$
   B. $I_b = I_e - I_c$
   C. $I_b = I_c - I_e$
   D. I_b = Twice I_c

11. A decrease of the forward bias at the emitter junction of a transistor will cause the emitter current to increase.

   A. True
   B. False

12. The collector junction of a transistor is:

   A. Reverse bias for PNP and forward bias for NPN
   B. Forward bias at all times
   C. Reverse bias at all times
   D. Reverse bias for NPN and forward bias for PNP

13. The power for the output signal of a transistor amplifier is supplied by the input signal.

   A. True
   B. False

EXAM C 3.8 CONT'D.

14. The emitter and collector current of a transistor vary at the same percent, while the base does not.

    A. True
    B. False

15. PNP and NPN transistors have the same bias polarities.

    A. True
    B. False

16. Negative-ground circuits favor the use of PNP transistors.

    A. True
    B. False

17. The base current is much less than collector current.

    A. True
    B. False

18. Bipolar transistors may be checked for opens and shorts by using an ohmmeter.

    A. True
    B. False

19. The most common use of the transistor is as a rectifier.

    A. True
    B. False

20. The dopant on the base of a bipolar transistor is heavy.

    A. True
    B. False

EXAM KEY C 3.8

1. B
2. B
3. B
4. B
5. C
6. C
7. A
8. B
9. D
10. B
11. B
12. C
13. B
14. B
15. B
16. B
17. A
18. A
19. B
20. B

ELECTRONICS

ANALYZING SOLID STATE DEVICES

C 4: COMMON-BASE AMPLIFIER

TASK:	From a schematic diagram, analyze, construct, and troubleshoot a common-base amplifier.
PURPOSE:	The most common method used in classifying amplifiers is according to the circuit configuration. When a transistor is used as an amplifying device, it can be classified according to the way in which the emitter, base, and collector are connected to the input and output circuits. If the input and output are connected in common with the base, it is known as a common-base amplifier. In this task you will explore the characteristics of a common-base amplifier.
OBJECTIVE:	Given the necessary information on the characteristics of a common-base amplifier, you will analyze, construct and troubleshoot a common-base amplifier. You must score at least 80% on a written exam and laboratory performance.

ESTIMATED CLASS TIME: 6 HOURS

COMMON BASE AMPLIFIER

LEARNING STEPS

C 4

READ: Information Sheet C 4.1, "Characteristics of the Common-Base Amplifier."

READ: Information on the characteristics of the common-base amplifier from the following resource list.

COMPLETE: Activity Sheet C 4.2, "Characteristics of the Common-Base Amplifier."

READ: Information Sheet C 4.3, "Measuring Current Gain of a Common Base Amplifier."

READ: Information on measuring current gain of a common-base amplifier from the following resource list.

COMPLETE: Activity Sheet C 4.4, "Measuring Current Gain of a Common Base Amplifier."

READ: Information Sheet C 4.5, "Measuring Alpha Cut-off and Collector-To-Base Leakage Current."

READ: Information on measuring alpha cut-off and collector-to-base leakage current from the following resource list.

COMPLETE: Activity Sheet C 4.6, "Measuring Alpha Cut-off and Collector-to-Base Leakage Current."

COMPLETE: Lab Performance from a schematic diagram, analyze, construct, and troubleshoot a common-base amplifier. Contact your instructor.

COMPLETE: Lab Performance Checklist C 4.7. Contact your instructor.

COMPLETE: Exam C 4.8.

THE COMMON BASE AMPLIFIER

RESOURCES

C 4

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1985). Fifth Edition.
2. Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). Fifth Edition.
3. Badrkhan and Larky, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984).
4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS (McGraw-Hill, 1984). Second Edition.
5. SEMICONDUCTOR DEVICES (Heath Company, 1982). Eighteenth Printing.

RECOMMENDED EQUIPMENT

0 - 24 VDC power supply
Volt - Ohmmeter or digital multimeter
Dual - trace oscilloscope
Various transistors

INFORMATION SHEET

C 4.1

CHARACTERISTICS OF THE COMMON-BASE AMPLIFIER

The common-base amplifier is another type of transistor amplification. In a common-base amplifier, the base is in common with the input and output signals. The common-base amplifier is important because it has specific characteristics concerning current gain, voltage gain, power gain, input and output impedance, and phase relationships between input and output signals.

The common-base amplifier configuration will provide a voltage gain and power gain, but not a current gain. The input signal is applied between the transistor's emitter and base. The output signal is developed across the load resistor between the base and collector. Since the collector current is smaller than the emitter current, the circuit cannot provide a current gain.

The common-base amplifier is not widely used, but it is necessary to examine the characteristics of the circuit. To show the electrical characteristics of the circuit, it is necessary to plot a number of characteristic curves. Refer to Figure C 4.1-1 for a typical circuit. With the use of this circuit you can plot the current-voltage relationship of a common-base amplifier. Figure C 4.1-2 illustrates a family of characteristic curves. From previous studies you should be able to interpolate curves of this nature; if not, the subject is covered in one or more of the resource materials listed in this guide.

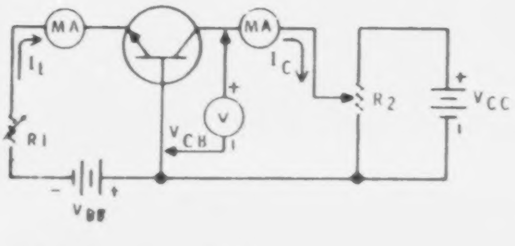


Figure C 4.1-1

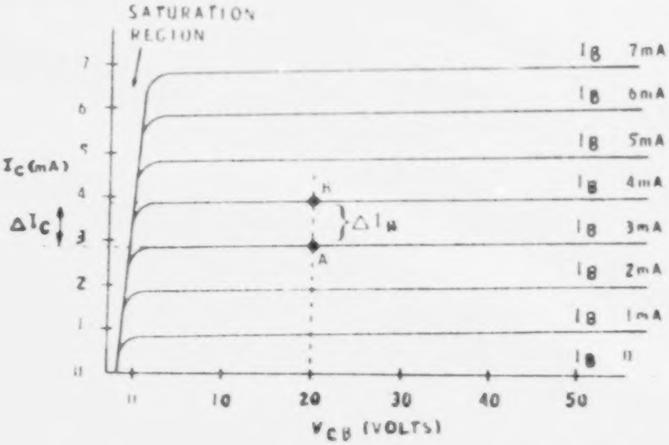


Figure C 4.1-2

ACTIVITY SHEET

C 4.2

1. Only NPN transistors can be used as common-base amplifiers.

   A. True
   B. False

2. Where is the input applied in a common-base amplifier?

3. The collector characteristic curves for a common-base transistor show the relationship between I_c and V_{cb} for various values of ________________.

4. Referring to Figure C 4.1-2, when V_{cb} is 40 volts and I_e is 4mA, the collector current is approximately ______________ mA.

5. At one point on the characteristic curve of a common-base amplifier, I_c is equal to I_e.

   A. True
   B. False

6. The common-base amplifier has no current amplification.

   A. True
   B. False

ACTIVITY SHEET KEY C 4.2

1. B
2. Base and emitter
3. Emitter current I
4. 3.8
5. B
6. A

INFORMATION SHEET

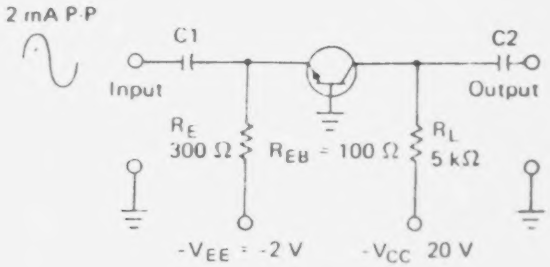
C 4.3

MEASURING CURRENT GAIN OF A COMMON-BASE AMPLIFIER

As you know from previous studies, the common-base amplifier cannot have a current gain, as we normally apply the word "gain." The current gain of a common-base amplifier is often identified by the greek letter and is expressed mathematically as follows: current gain (α) = $\frac{I_c}{I_e}$

Since the collector current will always be slightly less than the emitter current, the current gain will normally vary between .95 and .995. Please refer to Figure C 4.3-1 to verify this. The transistor's alpha is sometimes referred to as the "forward current transfer" and represented by the symbol h_{fb} for AC current transfer. For DC current transfer the symbol used will be h_{fb}.

Manufacturers of transistors usually state the alpha value for each type of transistor they produce. A symbol often used for current gain is A_i and for voltage gain, A_v.



Common Base Amplifier

Figure C 4.3-1

ACTIVITY SHEET

C 4.4

1. The current gain of a common-base amplifier is referred to as ____________________.

2. Alpha is the ratio of ____________ to ____________ current in a common-base amplifier.

3. A practical way of providing bias voltages in a common-base amplifier is by using a ________________ network.

4. A transistors alpha will always be less than ________________.

5. Only NPN transistors may be used as common-base amplifiers.

   A. True
   B. False.

6. For a common-base amplifier the input current is the emitter current.

   A. True
   B. False

7. In a common-base amplifier the output current is the emitter current.

   A. True
   B. False

8. If the change in emitter current of 1 mA causes a collector change of 0.95mA, the current gain is ____________________.

9. If a change of .4 volts in the emitter base causes a change of 8 volts in the collector base, the voltage gain is ____________________.

10. The output waveshape of a common-base amplifier is _______________ phase with the input.

ACTIVITY SHEET KEY C 4.4

1. Alpha
2. collector, emitter
3. Voltage divider
4. One
5. B
6. A
7. B
8. .95
9. 20
10. In

INFORMATION SHEET

C 4.5

MEASURING ALPHA CUT-OFF AND COLLECTOR-TO-BASE LEAKAGE CURRENT

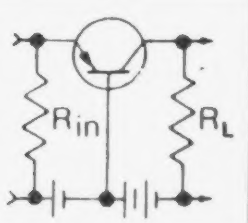
Like most active devices, the transistor has limitations as the frequency of the input signal is increased. When the time for one hertz (period) nears the transit time of the transistor, the gain of the transistor drops rapidly. The frequency at which the gain of the transistor drops to 70.7% of its low-frequency value is called the "alpha cut-off frequency" and is represented by the symbol "f_{ab}." This is a very important characteristic of a transistor, and must be considered when selecting a transistor for a specific circuit. The reference frequency used most widely is 1000 Hertz.

Referring to the characteristic curves of a transistor, you will note that when I_e is reduced to zero, a small current will flow through the transistor. Even though this is a small current (I_{cbo}), it is an important consideration, because it combines with and becomes a part of the collector current (I_c). Silicon transistors have a lower value of I_{cbo} than comparable germanium transistors.

INFORMATION SHEET C 4.5 CONT'D.

Only in critical circuits is I_{cbo} an important factor. As a summary of the characteristics of the common-base amplifier, study Figure C 4.5-1.

Figure C 4.5-1



Characteristics	Common Base
Voltage Gain (A_V)	High
Current Gain (A_i)	Low
Power Gain (A_P)	Medium
Input Impedance (Z)	Low
Output Impedance (Z)	High
Phase Reversal	No

ACTIVITY SHEET

C 4.6

1. The common-base amplifier has the ability to operate at unlimited frequencies.

   A. True
   B. False

2. The symbol for the collector-to-base leakage current is:

   A. f_{ab}
   B. I_c
   C. I_{cb}
   D. I_{cbo}

3. The reference frequency to establish the alpha cut-off is:

   A. 10 Hertz
   B. 60 Hertz
   C. 1000 Hertz
   D. 10,000 Hertz

4. The alpha cut-off frequency symbol is:

   A. f_o
   B. f_b
   C. f_{ab}
   D. f_{bc}

5. The collector-to-base leakage current should be considered in every circuit employing a common-base amplifier.

   A. True
   B. False

6. The collector-to-base leakage current is always 70.7% of the base current.

   A. True
   B. False

7. As a rule, silicon transistors have a lower collector-to-base leakage current.

   A. True
   B. False

ACTIVITY SHEET KEY C 4.6

1. B
2. D
3. C
4. C
5. B
6. B
7. A

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PROGRAM: ELECTRONICS

TASK: COMMON-BASE AMPLIFIER

TASK # C 4.7

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

PERFORMANCE OBJECTIVE:

From a schematic diagram, analyze, construct, and troubleshoot a common-base amplifier.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 80 out of 100 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 and must score 80 out of 100 points or 80% , and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

COMMON BASE AMPLIFIER

C 4.7

CRITICAL ITEMS	ITEMS TO BE OBSERVED OR CHECKED	RATING YES/NO
1.	Does circuit function properly?	Y N
*2.	Was circuit wired according to schematic?	Y N
3.	Are connections correct?	Y N
4.	Was necessary data recorded?	Y N
5.	Was correct equipment used?	Y N
*6.	Was equipment used properly?	Y N
*7.	Were safety precautions followed?	Y N
8.	Was equipment returned to proper storage?	Y N

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

SCORE _____

COMMON-BASE AMPLIFIER

EXAM C 4.8

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on common-base amplifiers. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. Do not write on this test!!!!! To master this exam you must answer 16 out of 20 items correctly, or 80%.

EXAM C 4.8

1. The input of a common-base amplifier is applied at ________.

   A. Base and emitter
   B. Base and collector
   C. Emitter and collector

2. Only NPN transistors may be used in the common-base amplifier.

   A. True
   B. False

3. In the common-base amplifier, I_c equals I_e.

   A. True
   B. False

4. The common-base amplifier has a small current gain.

   A. True
   B. False

5. The current gain of a common-base amplifier is expressed as ______________.

   A. Alpha
   B. Beta
   C. F_{co}
   D. h_{ef}

6. The alpha of a common-base amplifier is the ratio of the ______________ current to the __________________ current.

   A. Base, emitter
   B. Base, collector
   C. Collector, emitter
   D. Emitter, collector

7. The alpha of a common-base amplifier will vary between _____________ and _______________.

   A. 10, 200
   B. 1, 10
   C. 1, 2
   D. .9, .995

8. The input and output waveshapes of a common-base amplifier are ____________________ phase.

   A. In
   B. Out

9. If a change of .2 volts in the emitter base causes a change of 10 volts in the collector base, the A is _______.

   A. 2
   B. 10.2
   C. 9.8
   D. 50

10. In a common-base amplifier the input current is the _____________ current.

   A. Emitter
   B. Base
   C. Collector
   D. Emitter and collector

11. If a change of 1 mA in the emitter current of a common-base amplifier causes a change of .9 mA in the collector, the A_i is _______.

   A. 1.9
   B. .9
   C. 1
   D. .1

12. The symbol for collector-to-base leakage current is _______.

   A. I_c
   B. I_e
   C. I_l
   D. I_{cbo}

13. The symbol for the alpha cut-off is ___________:

   A. f_{bc}
   B. f_{ba}
   C. f_{ab}
   D. f_{cb}

EXAM C 4.8 CONT'D.

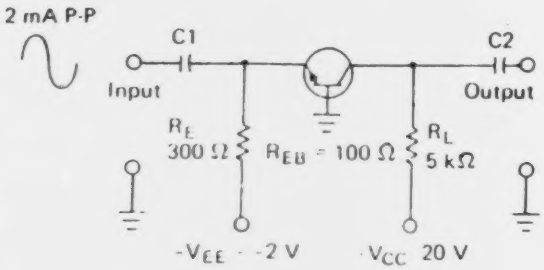
14. The collector-to-base leakage current of a common-base amplifier will be 70.7% of its collector current.

A. True
B. False

15. As a rule, silicon transistors have higher collector-to-base leakage current.

A. True
B. False

Refer to Figure C 4.8-1 for questions 16 through 20.


2 mA P-P
C1
C2
Input
Output
R_E 300 Ω
R_{EB} = 100 Ω
R_L 5 kΩ
$-V_{EE}$ = -2 V
V_{CC} 20 V

Common Base Amplifier

Figure C 4.8-1

16. The emitter current (I_e) will be ________________ mA.

A. 2
B. 6
C. 1.5
D. 5

17. The forward bias will be ________________ volts.

A. 2
B. 5
C. 1.5
D. .2

18. If a change of 2 mA in the emitter results in a change of 1.95 mA in the collector, the current gain (A_i), will be:

A. .095
B. 3.95
C. .975
D. 1.05

EXAM C 4.8 CONT'D.

19. If a change in the emitter-base voltage of .2 volts results in a change of 12 in the collector base, the voltage gain (A_v) is __________.

    A. 7.2
    B. 60
    C. 24
    D. 72

20. If the resistive value of the collector load resistor is raised, the current gain (A_i) will be __________.

    A. Same
    B. Higher
    C. Lower

EXAM KEY C 4.8

1. A
2. B
3. B
4. B
5. A
6. C
7. D
8. A
9. D
10. A
11. B
12. D
13. C
14. B
15. B
16. D
17. A
18. C
19. B
20. C

ELECTRONICS

ANALYZING SOLID STATE DEVICES

C 5: COMMON-EMITTER AMPLIFIER

TASK: From a schematic diagram, analyze, construct and troubleshoot a common-emitter amplifier.

PURPOSE: The most common method used in classifying amplifiers is according to the circuit configuration. When a transistor is used as an amplifying device, it can be classified according to the way in which the emitter, base, and collector are connected to the input and output circuit. If the input and output are connected in common with the emitter, it is known as a common-emitter amplifier. In this task you will explore the characteristics of a common-emitter amplifier.

OBJECTIVE: Given the necessary information on the characteristics of a common-emitter amplifier, you will analyze, construct and troubleshoot a common-emitter amplifier. You must score at least 80% on a written exam and laboratory performances.

ESTIM[illegible] TIME: 6 HOURS

COMMON EMITTER AMPLIFIER

LEARNING STEPS

C 5

READ: Information Sheet C 5.1, "Characteristics of a Common-Emitter Amplifier."

READ: Information on characteristics of a common emitter amplifier from the following resource list.

COMPLETE: Activity Sheet C 5.2, "Characteristics of a Common Emitter Amplifier."

READ: Information Sheet C 5.3, "Measuring the Current Gain of a Common-Emitter Amplifier."

READ: Information on measuring current gain of common-emitter amplifiers from the following resource list.

COMPLETE: Activity Sheet C 5.4, "Measuring the Current Gain of a Common-Emitter Amplifier."

READ: Information Sheet C 5.5, "Measuring Common-Emitter Amplifier Beta Cut-off and Collector-to-Emitter Leakage."

COMPLETE: Activity Sheet C 5.6, "Measuring Common-Emitter Amplifier Beta Cut-Off and Collector-To-Emitter Leakage."

COMPLETE: Lab performance, from a schematic diagram, analyze, construct and troubleshoot a common-emitter amplifier. Contact your instructor.

COMPLETE: Lab Performance Checklist C 5.7. Contact your instructor.

COMPLETE: Exam C 5.8.

THE COMMON EMITTER AMPLIFIER

RESOURCES

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1985). Fifth Edition.
2. Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). Fifth Edition.
3. Badrkhan and Larky, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984).
4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS (McGraw-Hill, 1984). Second Edition.
5. SEMICONDUCTOR DEVICES (Heath Company, 1982). Eighteenth Printing.

RECOMMENDED EQUIPMENT

0 - 24 VDC power supply
Volt - ohmmeter or digital multimeter
Dual - trace oscilloscope
Various transistors

INFORMATION SHEET

C 5.1

CHARACTERISTICS OF THE COMMON-EMITTER AMPLIFIER

The common-emitter amplifier is important because it has specific characteristics concerning current gain, voltage gain, power gain, input and output impedances, and phase relationship between input and output signals.

When a bipolar transistor is connected in a common-emitter configuration, the input signal is applied between the emitter and base. This causes the collector current to be controlled by the base current. Since the collector current is much larger than the base current, this in effect gives the circuit a current amplification. The amplified current is coming from the power sources of the transistor.

The current voltage relationship of a common-emitter can be analyzed by referring to a set of characteristic curves. The curves are plotted by measuring the collector current while varying the base current. Refer to Figure C 5.1-1 for a circuit used to measure these values. A typical set of characteristic curves is shown in Figure C 5.1-2. From previous studies you should be able to interpolate curves of this nature; if not, the subject is covered in one or more of the resource materials listed in this guide.

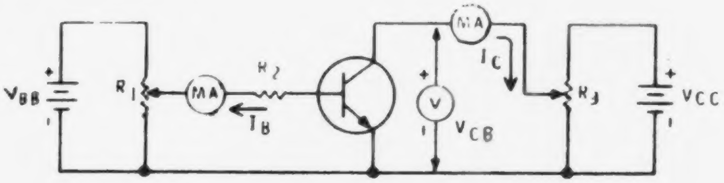


Figure C 5.1-1

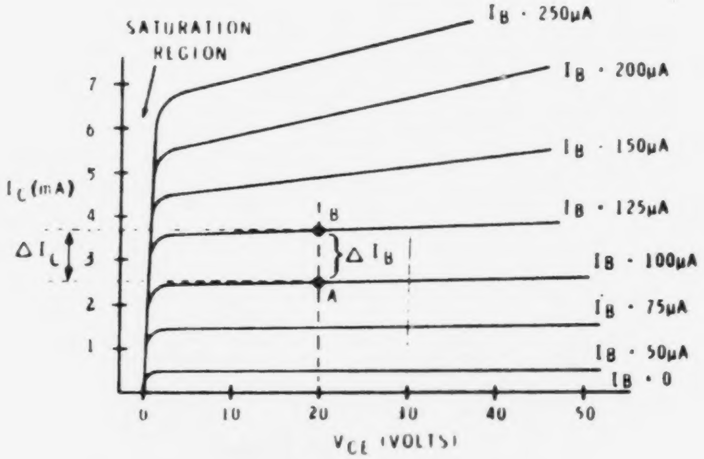


Figure C 5.1-2

ACTIVITY SHEET

C 5.2

1. The common-emitter transistor collector characteristic curves show the relationship of the transistor's collector current and the voltage applied to the __________ and __________.

2. In a common-emitter amplifier circuit, the input signal and the output signal both flow in the __________ of the transistor.

3. When a transistor is connected as a common-emitter amplifier, the base current is larger than the collector current.

   A. True
   B. False

4. In a common-emitter amplifier circuit, the collector current controls the base current.

   A. True
   B. False

5. The common-emitter amplifier circuit is the most widely used circuit in electronic equipment.

   A. True
   B. False

ACTIVITY SHEET KEY C 5.2

1. Collector, emitter
2. Emitter
3. B
4. B
5. A

INFORMATION SHEET

C 5.3

MEASURING THE CURRENT GAIN OF A COMMON-EMITTER AMPLIFIER

The amount of current gain amplification that a common-emitter amplifier can provide is easily calculated from the transistor's collector characteristic curves. The amount of current gain is based on how a change of base current changes the collector current. To determine this, we vary the base current, and then observe the corresponding change in the collector current. The current gain of a common-emitter amplifier transistor is identified by the greek letter beta (β) and is expressed mathematically as current gain (β) = $\frac{I_c}{I_b}$, with the collector voltage remaining constant. Referring to Figure C 5.1-3, with a collector voltage of 30 volts, and a change of base current from 100 μ A to 120 μ A, the collector current will change from 2.6 mA to 3.7 mA. Using the above formula the current gain of this specific transistor is calculated to be 44. At this time it would be well to solve several current gain problems from the resource materials listed in this guide.

Transistors have a current gain as low as 10, and as high as 200. Manufacturers of transistors often list the current gain for each transistor. The beta value is a measurement of the transistor's ability to amplify a changing AC current and is often referred to as the "H_{fe}." The DC beta is referred to as "H_{fc}." If the alpha value of a transistor is known, it is possible to calculate the β using the following equation:

$$\beta = \frac{\alpha}{1 - \alpha}.$$

When the value is known, the alpha value can be determined by the following equation: $\alpha = \frac{\beta}{\beta + 1}$. The symbol often used for current gain is A_i, is also widely used as a symbol for voltage gain A_v.

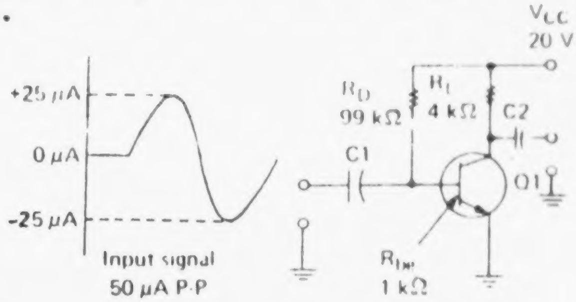


Figure C 5.1-3

ACTIVITY SHEET

C 5.4

1. In a common-emitter amplifier, the __________ is common to the input and output.

2. According to the Figure C 5.1-2, (following Information Sheet C 5.1), the collector voltage has little control over the collector current once the transistor is operating past the knee of each curve.

   A. True
   B. False

3. The current gain of a common-emitter amplifier is represented by the Greek letter __________.

4. The gain of a typical common-emitter amplifier may vary between __________ and __________.

5. Beta is the ratio of __________ current to __________ current in a common-emitter amplifier.

6. The voltage gain of any amplifier is the ratio of the __________ signal voltage to the __________ signal voltage.

7. The input signal is applied to the __________ of a common-emitter amplifier, and the output is taken from the __________.

8. A common-emitter amplifier __________ provide a power gain.

   A. Does
   B. Does not

9. According to Figure C 5.1-2 (following Information Sheet C 5.1), collector current will always be slightly less than base current.

   A. True
   B. False

10. The power gain of a common-emitter amplifier is determined by multiplying __________ by beta.

ACTIVITY SHEET KEY C 5.4

1. Emitter
2. A
3. Beta
4. 10 and 200
5. Output or collector, input or base
6. Output, input
7. Base, collector
8. A
9. B
10. Voltage gain

INFORMATION SHEET

C 5.5

MEASURING COMMON-EMITTER AMPLIFIER BETA CUT-OFF AND COLLECTOR-TO-EMITTER LEAKAGE

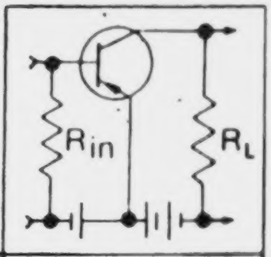
Like any active device used in electronic circuits, the common-emitter amplifier has a frequency limit at which it will operate effectively. This frequency is determined by the transit time of the transistor. When the time for one hertz (period) nears the transit time of the transistor, the gain drops very rapidly. The frequency at which the gain of a transistor drops to 70.7% of its low frequency gain is called the beta cut-off frequency. This is represented by the symbol F_{ab}. The reference frequency most often used will be 1000 hertz.

Referring to Figure C 5.1-2 (following Information Sheet C 5.1), you will find that when I_b is reduced to zero, a small amount of current flows through the transistor. This current is referred to as the collector-to- emitter leakage. It is referred to as I_{ceo}. I_{ceo} is important when selecting a transistor for a specific purpose, since it combines with the normal collector current than for normal bias operation.

INFORMATION SHEET C 5.5 CONT'D.

As a summary of the characteristics of the common-emitter amplifier study Figure C 5.5-1.

Figure C 5.5-1



Characteristics	**Common Emitter**
Voltage Gain (A_V)	High
Current Gain (A_I)	High
Power Gain (A_p)	Very High
Input Impedance (Z)	Medium
Output Impedance (Z)	Medium
Phase Reversal	Yes

ACTIVITY SHEET

C 5.6

1. The beta cut-off frequency of a transistor is the frequency at which its gain is reduced to 70.7% of its low frequency gain.

   A. True
   B. False

2. The reference frequency most often used as the beta cut-off reference is 10,000 hertz.

   A. True
   B. False

3. Beta cut-off is represented by the symbol F_{ab}.

   A. True
   B. False

4. A transistor's collector-to-emitter leakage current subtracts from the normal collector current.

   A. True
   B. False

5. A transistor's collector-to-emitter leakage current is represented by the symbol I_{ceo}.

   A. True
   B. False

6. The collector-to-emitter leakage current is so small it should never be considered in the design of a circuit.

   A. True
   B. False

ACTIVITY SHEET KEY C 5.6

1. A
2. B
3. A
4. B
5. A
6. B

PROGRAM: ELECTRONICS

TASK: COMMON-EMITTER AMPLIFIER

TASK # C 5.7

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ________________________ EVALUATION SITE ____________

EVALUATOR'S NAME ______________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ____________

PERFORMANCE OBJECTIVE:

From a schematic diagram, analyze, construct and troubleshoot a common-emitter amplifier.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 80 out of 100 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 80 out of 100 points or 80%, and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

COMMON-EMITTER AMPLIFIER

C 5.7

CRITICAL ITEMS	ITEMS TO BE OBSERVED OR CHECKED	RATING YES/NO
1.	Does circuit function correctly?	Y N
*2.	Was circuit wired according to schematic?	Y N
3.	Are connections correct?	Y N
4.	Was necessary data recorded?	Y N
*5.	Was correct equipment used?	Y N
*6.	Was equipment used properly?	Y N
*7.	Were safety precautions followed?	Y N
8.	Was equipment returned to proper storage?	Y N

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

SCORE ______

COMMON-EMITTER AMPLIFIER

EXAM C 5.8

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on the characteristics of a common-emitter amplifier. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. Do not write on this test!! To master this exam you must answer 16 out of 20 items correctly, or 80%.

EXAM

C 5.8

1. In a common-emitter amplifier the input and output signal flow in the ________________ and _______________.

   A. Emitter and base
   B. Emitter and collector
   C. Base and collector

2. The common-emitter amplifier is very seldom used in electronic circuits.

   A. True
   B. False

3. In a common-emitter amplified circuit, the base current controls the collector current.

   A. True
   B. False

4. When a transistor is connected as a common-emitter amplifier, the largest current flow is in the collector.

   A. True
   B. False

5. In a common-emitter amplifier circuit, the current gain is represented by ________________.

   A. Alpha
   B. Beta
   C. V_{cc}
   D. I_{ceo}

6. The current gain of a common-emitter amplifier will vary between ______________ and ________________.

   A. 0 and 100
   B. 100 and 200
   C. 10 and 100
   D. 10 and 200

EXAM C 5.8 CONT'D.

7. In a common-emitter amplified circuit, the input signal is applied to the ________________.

   A. Base
   B. Emitter
   C. Collector
   D. Base and collector

8. In a typical common-emitter amplifier, the collector current will be ________________ the emitter current.

   A. Equal to
   B. More than
   C. Less than

9. Beta is the ratio of __________ to ____________.

   A. Base to collector
   B. Base to emitter
   C. Collector to emitter
   D. Collector to base

10. The common-emitter amplifier does not provide a power gain.

    A. True
    B. False

11. The beta cut-off frequency of a common-emitter amplifier is the frequency at which the circuit has __________ amplification.

    A. Most
    B. Least
    C. 70.7%
    D. Zero

12. The beta cut-off frequency is represented by ________.

    A. F_{ab}
    B. F_{b}
    C. F_{o}
    D. F_{bo}

13. A transistor collector-to-emitter leakage current is ______.

    A. Important
    B. Not important
    C. High
    D. Low

EXAM C 5.8 CONT'D.

14. A transistor's collector-to-emitter leakage current ____________ the collector current.

    A. Adds to
    B. Subtracts from
    C. Does not affect
    D. Doubles

15. The resistance of a transistor is controlled by the current through the ________________ junction.

    A. Emitter-collector
    B. Emitter-base

Refer to Figure C 5.8-1 below for Questions 16 through 20.

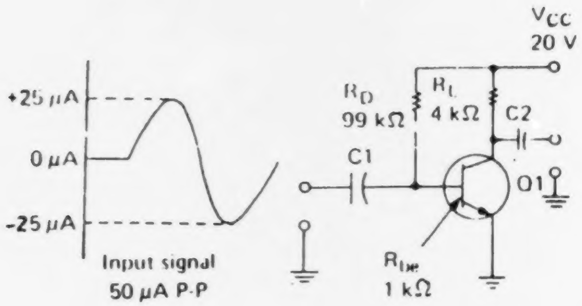


Figure C 5.8-1

16. The output waveshape of a common-emitter amplifier is ____________ with the input waveshape.

    A. In phase
    B. 180° out of phase

17. In a common-emitter amplifier circuit, if the resistive value of the collector load resistor is increased, the beta value of the circuit will ________________.

    A. Increase
    B. Decrease
    C. Remain the same

18. In Question 17, the voltage gain of the circuit would _____.

    A. Increase
    B. Decrease
    C. Remain the same

EXAM C 5.8 CONT'D.

19. The base current will be ______________ μA.

A. 25
B. 50
C. 0
D. 200

20. The forward-bias voltage will be ______________ V.

A. .002
B. .02
C. .2
D. 2.

EXAM KEY C 5.8

1. B
2. B
3. A
4. B
5. B
6. D
7. A
8. C
9. D
10. B
11. C
12. A
13. A
14. A
15. B
16. B
17. B
18. A
19. D
20. C

ELECTRONICS

ANALYZING SOLID STATE DEVICES

C 6: COMMON-COLLECTOR AMPLIFIER

TASK: From a schematic diagram analyze, construct, and troubleshoot a simple, common-collector amplifier.

PURPOSE: When a bipolar transistor is connected as a common-collector amplifier, the input signal is applied to the base and collector, with the output appearing between the emitter and collector. The common-collector amplifier has characteristics that the common-emitter and common-base do not have. As a result of these characteristics the common-collector amplifier has a definite use in electronics. We will explore these characteristics in this task.

OBJECTIVE: Given the necessary information on a common-collector amplifier, you will analyze, construct, and troubleshoot a common-collector amplifier. You must score at least 80% on a written exam and laboratory performance.

ESTIMATED CLASS TIME: 6 HOURS

COMMON-COLLECTOR AMPLIFIER

LEARNING STEPS

C 6

READ:	Information Sheet C 6.2, "Characteristics of a Common-Collector Amplifier."
READ:	Information on characteristics of a common-collector amplifier from the following resource list.
COMPLETE:	Activity Sheet C 6.2 , "Characteristics of a Common-Collector Amplifier."
READ:	Information Sheet C 6.3, "Transistor Ratings."
READ:	Information on transistor ratings from the following resource list.
COMPLETE:	Activity Sheet C 6.4, "Transistor Ratings."
COMPLETE:	Lab Performance, characteristics of a common-collector amplifier. Contact your instructor.
COMPLETE:	Lab Performance Checklist C 6.5. Contact your instructor.
COMPLETE:	Exam C 6.6.

COMMON-COLLECTOR AMPLIFIER

RESOURCES

C 6

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1985). Fifth Edition.
2. Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). Fifth Edition.
3. Badrkhan and Lark, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984).
4. Schuler, ELECTRONICS: PRINCIPLES AND APPLICATIONS (McGraw-Hill, 1984). Second Edition.
5. SEMICONDUCTOR DEVICES (Heath Company, 1982). Eighteenth Printing.

RECOMMENDED EQUIPMENT

0 - 24 VDC power supply
Volt - ohmmeter or digital multimeter
Dual - trace oscilloscope
Various transistors

INFORMATION SHEET

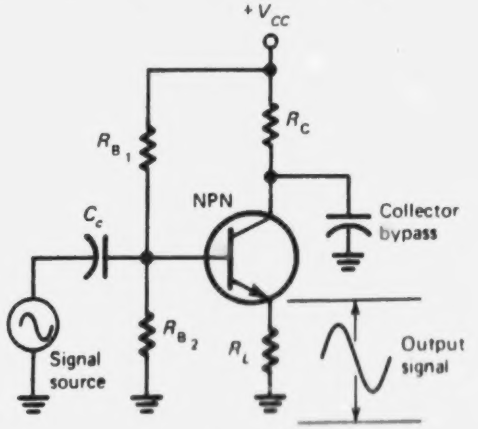
C 6.1

CHARACTERISTICS OF A COMMON-COLLECTOR AMPLIFIER

From previous studies we learned the most widely used transistor amplifier was the common emitter. However the input and output impedance of the common emitter falls in the medium category. There are times, due to circuit condition, that other input and output impedances are needed. In many cases the common-collector is suitable for this application. It has a high-input and low-output impedance. Many times it can be used as an amplifier as well as an impedance matching device.

Please refer to Figure C 6.1-1 for a common-collector amplifier circuit. Note that it appears the same as a common emitter, the difference being that the output is taken from the emitter resistor.

Figure C 6.1-1



The common-collector amplifier cannot produce a voltage gain, due to the fact that the emitter voltage (output) has a tendency to follow the bias voltage (input). This circuit will have a high current gain (A_v) and a moderate power gain (A_pp). Since the output voltage tends to follow the input voltage, this circuit is often referred to as an emitter follower.

The transistor's current gain (Gamma) is expressed mathematically as:

$$\text{current gain} = \frac{\Delta I_e}{\Delta I_b}$$

Also from previous studies you found that $I_e = I_b$ b + I_c; now you can mathematically change the current gain formula to:

$$\text{current gain} = 1 + \beta.$$

INFORMATION SHEET C 6.1 CONT'D

This may be used for both AC and DC signals.

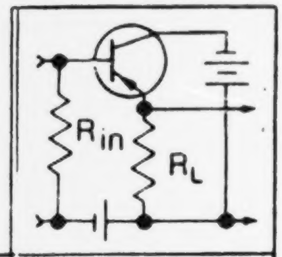
The approximate input resistance of the common-collector amplifier can be obtained by using the following equation:

$$R_{IN} = \beta R_L$$

The approximate output resistance of the common-collector amplifier can be obtained by dividing the input resistance by the β.

As a summary of the characteristics of a common-collector amplifier, study Figure C 6.1-2 to become more familiar with the circuit.

Figure C 6.1-2



Characteristics	Common Collector
Voltage Gain (A_V)	Low
Current Gain (A_I)	High
Power Gain (A_P)	Low
Input Impedance (Z)	High
Output Impedance (Z)	Low
Phase Reversal	No

ACTIVITY SHEET

C 6.2

1. If a transistor has a high beta, for practical purposes the current gain of the circuit would be the beta value.

   A. True
   B. False

2. The current gain of a common-collector amplifier is equal to 1 plus the transistor ______________________________.

3. In a common-collector amplifier the input current is the ____________________ current.

4. In a common-collector amplifier the output current is the ____________________ current.

5. The common-collector amplifier schematic looks similar to the ____________________ circuit.

6. The current gain of a common-collector amplifier is referred to as __________________.

7. The voltage gain of a common-collector amplifier is the ratio of the ________________ current to the ________________.

8. The output voltage is more than the input voltage.

   A. True
   B. False

9. The waveshape of the output of a common-collector amplifier is out of phase with the input.

   A. True
   B. False

10. Manufacturers of transistors always specify the important characteristics of the three configurations of transistor amplifiers.

   A. True
   B. False

ACTIVITY SHEET KEY C 6.2

1. A
2. Beta
3. Base
4. Emitter
5. Common Emitter Amplifier
6. Gamma
7. Output, Input
8. B
9. B
10. B

INFORMATION SHEET

C 6.3

TRANSISTOR RATINGS

So far in our study of transistors we have covered the three circuit configurations of transistor amplifiers. For each case we assumed the transistor was operating within its safe operating limits. As with diodes, which have current and voltage limitations, transistors also have current and voltage limits.

Manufacturers usually specify the maximum voltage and current the device can withstand. Often they specify the various power and temperature limitations.

When this information is not available, it becomes necessary to check data sheets or substitute transistors.

The collector-breakdown voltage occurs when the transistor's collector-base junction breaks down in the same manner as a diode breaks down. The collector-breakdown is referred to as V_{cbo} or BV_{cbo}.

The emitter-breakdown voltage is the voltage required to break down the emitter-base junction. This voltage is referred to as V_{cbo} or BV_{cbo}. Some manufacturers also list reverse leakage current.

Another listing on a transistor will be the maximum collector and emitter current. These are represented by the symbol I_c and I_e.

Since a transistor has some internal resistance, power is produced by the current flowing through the junction. The amount of power a transistor can safety dissipate at its collector junction is referred to as the transistor's maximum collector dissipation rating. These ratings will vary from a few milliwatts to over 100 watts.

From previous studies of the diode, we are aware of the effect temperature has on junctions. Just like diodes, transistors have a limit on their operating temperatures. Manufacturers usually specify the maximum operating temperature for each type of transistor.

ACTIVITY SHEET

C 6.4

1. The operating temperature of a transistor affects its ____________________ rating.
2. The symbol V_{cbo} will be used to indicate the ______________ voltage.
3. The amount of power a transistor can safely dissipate is called its __________________.
4. The beta of a transistor can be affected when its maximum operating ________________ is exceeded.
5. The symbol V_{ebo} is referred to as the transistor's ______________ _______________ voltage.
6. The larger the case of a transistor, the more voltage it can withstand without breakdown.

   A. True
   B. False
7. The heat sink is used to help radiate the _________________ of a transistor.

ACTIVITY SHEET KEY C 6.4

1. Power Dissipation
2. Collector Breakdown
3. Maximum Collector Dissipation
4. Temperature
5. Emitter - Base
6. B
7. Heat

PROGRAM: ELECTRONICS

TASK: COMMON-COLLECTOR AMPLIFIER

TASK # C 6.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S ______________________________ EVALUATION SITE ____________

EVALUATOR'S NAME ______________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ____________

PERFORMANCE OBJECTIVE:

From a schematic diagram analyze, construct, and troubleshoot a simple, common-collector amplifier.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 80 out of 100 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 80 out of 100 points or 80%, and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

COMMON-COLLECTOR AMPLIFIER

C 6.5

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
1.	Does circuit function correctly?	Y	N
*2.	Was circuit wired according to schematic?	Y	N
*3.	Are connections correct?	Y	N
4.	Was necessary data recorded?	Y	N
5.	Was correct equipment used?	Y	N
*6.	Was equipment used properly?	Y	N
*7.	Were safety precautions followed?	Y	N
8.	Was equipment returned to proper storage?	Y	N

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

SCORE _____

COMMON COLLECTOR AMPLIFIER

EXAM C 6.6

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on common-collector amplifiers. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!! To master this exam you must answer 16 out of 20 items correctly, or 80%.

EXAM C 6.6

1. In a common-collector amplifier with a beta of 10, the current gain is __________:

   A. 9
   B. 10
   C. 11
   D. 20

2. In a common-collector amplifier the emitter current is the ________.

   A. Base
   B. Collector
   C. Input
   D. Output

3. The current gain of a common-collector amplifier is referred to as its ____________.

   A. Alpha
   B. Beta
   C. Gamma
   D. Delta

4. The input current of a common-collector amplifier is the ____________ current.

   A. Emitter
   B. Base
   C. Collector
   D. Alpha

5. The voltage gain of a common-collector amplifier is the ratio of the ____________ current to the _________ current.

   A. output, input
   B. input, output
   C. base, collector
   D. collector, base

6. In a common-collector amplifier, the output voltage is always more than the input voltage.

   A. True
   B. False

EXAM C 6.6 CONT'D.

7. The output waveshape of a common-collector amplifier is in phase with the input.

   A. True
   B. False

8. Manufacturers seldom give the specifications for the three circuit configurations.

   A. True
   B. False

9. A common-collector amplifier provides both a current and voltage gain.

   A. True
   B. False

10. In a common-collector amplifier, the collector is common to the input and output signals.

    A. True
    B. False

11. The emitter resistor is used to radiate the heat of a transistor.

    A. True
    B. False

12. The operating temperature of a transistor affects its ______ ______________ rating.

    A. Breakdown-voltage
    B. Collector-breakdown
    C. Power-dissipation

13. The symbol V_{cbo} is used to indicate ____________ __________ voltage.

    A. Common-breakdown
    B. Emitter-breakdown
    C. Base-breakdown
    D. Collector-breakdown

EXAM 6.6 CONT'D.

14. The symbol V_{ebo} is used to indicate __________ _________ voltage.

    A. Common-breakdown
    B. Emitter-breakdown
    C. Base-breakdown
    D. Collector-breakdown

15. The size of a transistor case is an indication of its collector-breakdown voltage.

    A. True
    B. False

16. The signal fed into an amplifier is 100 mV. The output signal is 8.5 volts. The voltage gain of the amplifier is ___________.

    A. .85
    B. 8.5
    C. 85
    D. 850

17. The input impedance of a common-collector amplifier is __________.

    A. very low
    B. low
    C. high
    D. very high

Refer to Figure C 6.6-1 for questions 18 through 20

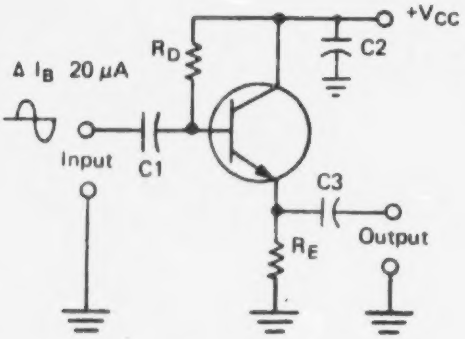


Figure C 6.1-3

18. The output voltage will be ________ the input voltage.

    A. larger than
    B. small than
    C. equal to
    D. twice

19. The voltage developed across R_e __________ the forward bias voltage.

    A. aids
    B. opposes
    C. has no effect on
    D. doubles

20. Regeneration feedback developed across R_e causes the voltage gain of the common-collector amplifier to be less than one.

    A. True
    B. False

EXAM KEY C 6.6

1. C
2. D
3. C
4. B
5. A
6. B
7. A
8. A
9. B
10. A
11. B
12. C
13. D
14. B
15. B
16. C
17. D
18. B
19. B
20. B

ELECTRONICS

ANALYZING SOLID STATE DEVICES

C 7: FIELD EFFECT TRANSISTOR

TASK: Examine the characteristics of the FET.

PURPOSE: The field effect transistor (FET) is a three-terminal device used primarily as an amplifier. The three terminals are called the source, drain, and gate. Outwardly the FET looks like an ordinary transistor. The FET has characteristics that make its operation more like a tube than that of a typical transistor. There are two types of field effect transistors. One type is known as the junction field effect transistor (JFET), commonly referred to as FET. The other is the insulated gate field effect transistor (IGFET), often referred to as a MOSFET. The FET is an important solid-state device, which we will examine in this task.

OBJECTIVE: Given the necessary information on the FET, you will examine the characteristics of the FET. To master this task you must score at least 80% on a written exam and laboratory performance.

ESTIMATED CLASS TIME: 10 HOURS

FIELD EFFECT TRANSISTOR

LEARNING STEPS

C 7

READ: Information Sheet C 7.1, "Construction and Operation of a FET."

READ: Information on the construction and operation of a FET from the following resource list.

COMPLETE: Activity Sheet C 7.2, "Construction and Operation of a FET."

READ: Information Sheet C 7.3, "Characteristics of a FET."

READ: Information on characteristics of a FET from the following resource list.

COMPLETE: Activity Sheet C 7.4, "Characteristics of a FET."

READ: Information Sheet C 7.5 "Depletion Mode of a FET."

READ: Information on depletion mode of a FET from the following resource list.

COMPLETE: Activity Sheet C 7.6, "Depletion Mode of a FET."

READ: Information Sheet C 7.7, "Enhancement Mode."

READ: Information on enhancement modes from the following resource list.

COMPLETE: Activity Sheet C 7.8, "Enhancement Mode."

COMPLETE: Lab Performance, examine the characteristics of the FET. Contact your instructor.

COMPLETE: Lab Performance Checklist C 7.9. Contact your instructor.

COMPLETE: Exam C 7.10.

FIELD EFFECT TRANSISTOR

RESOURCES

C 7

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1985). Fifth Edition.
2. Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). Fifth Edition.
3. Badrkhan and Lark, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984(.
4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS (McGraw-Hill, 1984). Second Edition.
5. SEMICONDUCTOR DEVICES (Heath Company, 1982. Eighteenth Printing.

RECOMMENDED EQUIPMENT

0 - 24 VDC power supply
Volt - Ohmmeter or digital multimeter
Dual - Trace oscilloscope
Various transistors
AF generator
RF generator

INFORMATION SHEET

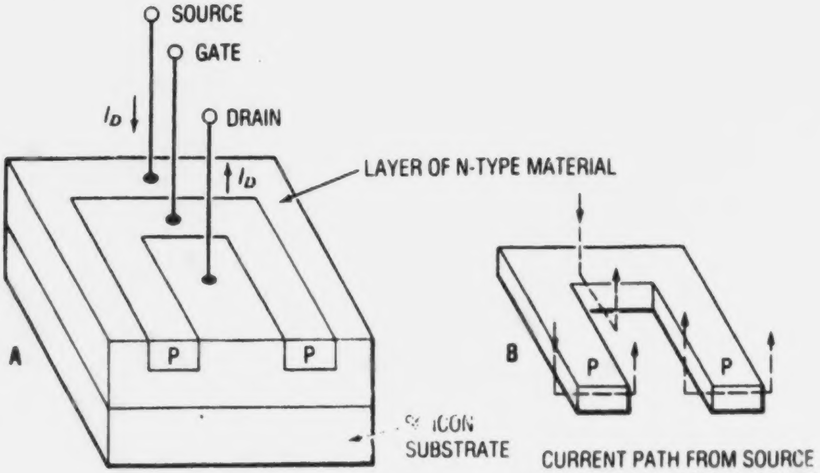
C 7.1

CONSTRUCTION AND OPERATION OF A FET

The FET serves the same function as a junction transistor, but the FET construction provides a very high input impedance, usually in the megohms. The input to the FET can handle much larger volt input signals than junction transistor.

Figure C 7.1-1 shows the construction of an N-channel FET. The bulk of substrate material is neutral or lightly-doped silicon. It serves as a platform for the other electrodes. If the channel material is N-type, it is known as a N-channel FET. Likewise, if P-type material is used, it is known as P-channel FET. The three leads to the FET are known as gate, source, and drain. Figure C 7.1-2 represents the symbol for an N-channel type and Figure C 7.1-3 is the symbol for a P-channel type.

Figure C 7.1-1


SOURCE
GATE
DRAIN
I_D
I_D
LAYER OF N-TYPE MATERIAL
A
P
P
SILICON SUBSTRATE
B
P
P

CUTAWAY VIEW OF A PRACTICAL FET CONSTRUCTION

CURRENT PATH FROM SOURCE TO DRAIN IS UNDER THE P-TYPE MATERIAL

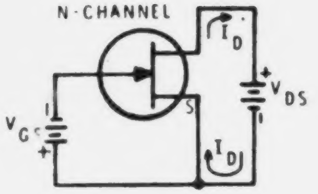

N-CHANNEL
I_D
V_{DS}
V_{GS}
S
I_D

Figure C 7.1-2

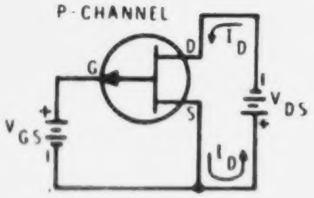

P-CHANNEL
D
I_D
G
V_{DS}
V_{GS}
S
I_D

Figure C 7.1-3

INFORMATION SHEET C 7.1 CONT'D.

Like the bipolar transistor, the FET requires two bias voltages. Referring to C 7.1-4, the voltage V_{ds} is connected between the drain and source in such manner that the source is made negative to the drain. Under those conditions, current will flow through the channel; this is called the FET's drain current. The second bias voltage (V_{os}) is connected between the gate and source, with the gate negative with respect to the source. By controlling the depletion region, the V_{os} can control the drain current.

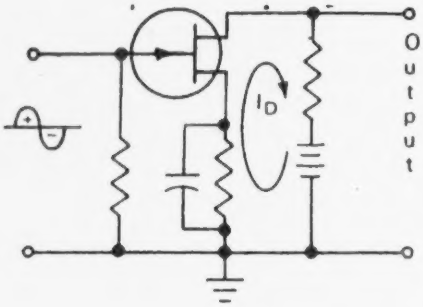


Figure C 7.1-4

In normal operation, the voltage applied to the gate and source (V_{os}) will be the input signal, and will control the device. The drain current will flow through the load resistor to develop the output signal. This action is different than the bipolar transistor, in which the output is controlled by the input current. In the FET, the output is controlled by the input voltage.

A further study should be made on this device from the material listed in this learning guide.

ACTIVITY SHEET

C 7.2

1. The part of the JFET that supports the electrodes of transistors is known as the __________.

2. Referring to Question 1, this material is usually made of __________.

3. The three leads of the JFET are called the __________ and __________ and ____________ .

4. In the JFET, the current is made to flow through the __________.

5. In an N-channel JFET, the majority carriers are __________.

6. In a P-channel JFET, the majority carriers are __________.

7. On most JFET's you can reverse the source and drain leads.

   A. True
   B. False

8. The input resistance of a JFET is lower than that of a bipolar transistor.

   A. True
   B. False

9. The current that flows through the channel of a JFET is called the __________ current.

10. In normal operation, the input signal will be connected to the __________.

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ACTIVITY SHEET KEY C 7.2

1. substrate
2. silicon
3. gate, drain, source
4. channel
5. electrons
6. holes
7. A
8. B
9. drain
10. gate

INFORMATION SHEET

C 7.3

CHARACTERISTICS OF A FET

Referring to Figure C 7.3-1, with a small V the depletion is small and allows drain current to flow. As V is increased (Figure C 7.3-2) the depletion region grows larger, reducing the drain current further. As V_{gs} is further increased, the drain current is reduced to zero for practical purposes. The amount of V_{gs} to cause this condition is referred to as the "gate-to-source cutoff voltage" and is represented by the symbol V_{gs} (off). Manufacturers usually supply the V_{gs} (off) for each type of FET they produce.

Figure C 7.3-1

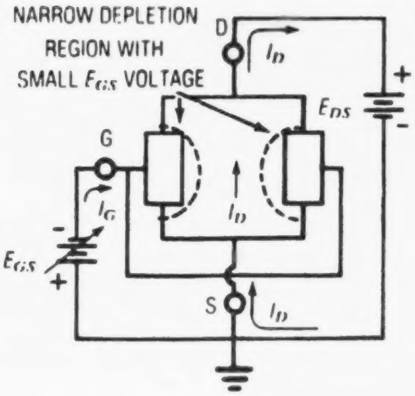
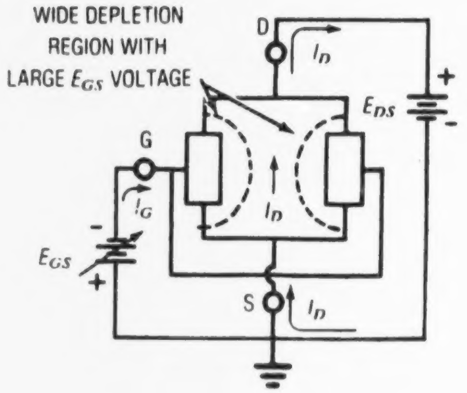
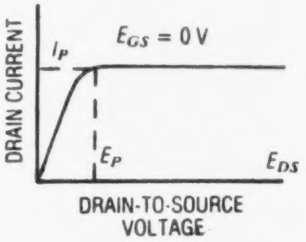

NARROW DEPLETION REGION WITH SMALL E_{GS} VOLTAGE
D
I_D
E_{DS}
+
-
G
I_G
I_D
-
E_{GS}
+
S
I_D

Figure C 7.3-2


WIDE DEPLETION REGION WITH LARGE E_{GS} VOLTAGE
D
I_D
E_{DS}
+
-
G
I_G
I_D
-
E_{GS}
+
S
I_D

If the voltages increase between the drain and source, this causes the drain current (I_d) to increase. The drain current increases to a certain point; after that an increase in V_p does not cause an increase in I_d. This point is called the "pinch-off" voltage (V_p). This is represented by Figure C 7.3-3.

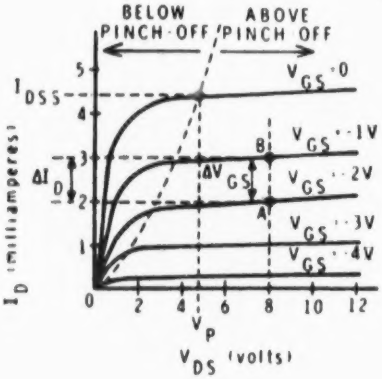
Figure C 7.3-3



INFORMATION SHEET C 7.3 CONT'D.

In previous studies you saw how a set of collector characteristics curves can show the relationship between the input and output currents. A similar set of curves for the FET is shown in Figure C 7.3-4.

Figure C 7.3-4



Like the bipolar transistor, the FET is most often used to amplify signals. The amplifying of a FET is measured by the effect that V_{gs} has over I_d. This ratio is referred to as "transconductance" and is expressed mathematically as $gm = \frac{\Delta I_d}{\Delta V_{gs}}$

The transconductance of a FET is expressed in units called "mhos."

ACTIVITY SHEET

C 7.4

1. What is the primary application for a FET?

2. Increasing the V_{gs} causes the depletion region to __________.

3. When the V_{gs} causes drain current to cease to flow, this point is called the ________ voltage.

4. The gain of a FET is measured in __________.

5. A FET is biased so that an increase in V_{gs} causes the drain current to __________.

6. A P-channel FET is biased so that its drain is positive with respect to its source.

   A. True
   B. False

7. The transconductance of a FET is determined by dividing a small change in __________ by a small change in V_{gs}.

8. If the arrow points out in a FET symbol, this indicates the channel is made of __________-type material.

ACTIVITY SHEET KEY C 7.4

1. amplifier
2. increase
3. cut-off
4. mhos
5. decrease
6. B
7. I_d
8. P

INFORMATION SHEET

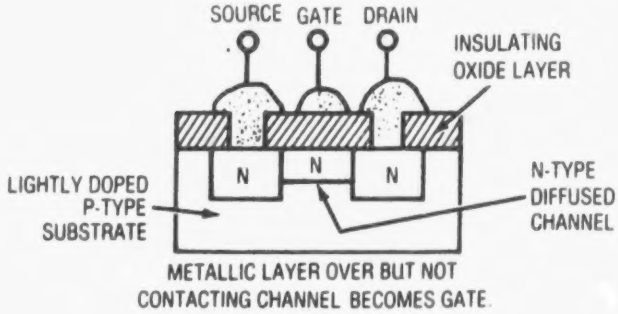
C 7.5

DEPLETION-MODE OPERATION OF AN IGFET

The gate and channel regions within a junction FET form a conventional PN junction. By applying a reverse current at this junction, the bias will control the drain current. However, there is another type of FET which does not have this type of construction. This device has an insulated gate, using a metal oxide semiconductor (mos) material. This device is known as a "metal-oxide semiconductor field effect transistor" (IGFET). It is also known as a MOSFET. The MOSFET can operate in two different modes, depletion or enhancement.

Refer to Figure C 7.5-1 for the construction of the depletion-mode MOSFET. You will note the gate is insulated from the semiconductor material. This layer of silicon dioxide acts as an insulation; however, the insulated gate can be used to control the conductivity of the channel. When the gate of the IGFET becomes sufficiently negative, it depletes the majority carriers out of the channel. The channel is narrowed and thus reduces or cuts off the drain current. When the gate of the IGFET becomes more positive, this helps to attract majority carriers and the result is increased drain current.

Figure C 7.5-1


SOURCE
GATE
DRAIN
INSULATING OXIDE LAYER
N
N
N
LIGHTLY DOPED P-TYPE SUBSTRATE
N-TYPE DIFFUSED CHANNEL
METALLIC LAYER OVER BUT NOT CONTACTING CHANNEL BECOMES GATE

One of the differences between the operation of the JFET and the IGFET is the input resistance. If a JFET has a positive voltage on the gate, this causes forward-bias conditions, which lowers the input resistance. If an IGFET has a positive voltage on the gate, this does not happen, because the gate is insulated. The gate input resistance is unaffected by the polarity of the gate voltage.

INFORMATION SHEET C 7.5 CONT'D.

The symbol for an N-channel depletion mode IGFET is shown in Figure C 7.5-2.

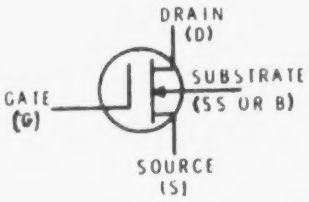

DRAIN
(D)
SUBSTRATE
(SS OR B)
GATE
(G)
SOURCE
(S)

Figure C 7.5-2

ACTIVITY SHEET

C 7.6

1. What force controls the flow of electrons through the channel of an IGFET?

2. A depletion-mode IGFET can be either a __________-channel or __________-channel.

3. Majority carriers in an N-channel depletion-mode IGFET will be __________.

4. When the gate of an N-channel depletion-mode IGFET is made sufficiently negative, the drain current will be __________.

5. An IGFET has a metallic gate that is insulated from its __________.

6. The bias voltages required for a P-channel depletion-mode IGFET are the same as required for an N-channel depletion mode IGFET.

   A. True
   B. False

ACTIVITY SHEET KEY C 7.6

1. gate, voltage
2. N, P
3. electrons
4. decrease
5. channel
6. B

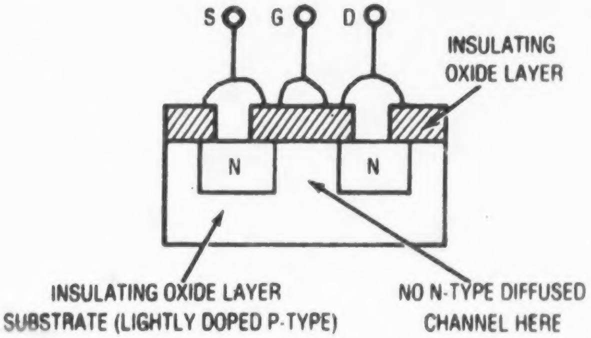
INFORMATION SHEET

C 7.7

ENHANCEMENT-MODE OPERATION OF AN IGFET

As explained previously, the depletion-mode IGFET is normally a device; as long as a V_{ds} is applied, there will be drain current, even if V_{gs} is zero. An IGFET will operate normally as an "off" device if it is constructed as shown in Figure C 7.7-1. The lightly doped layer diffused in the substrate is not included in this IGFET. This type of IGFET is known as the enhancement-mode IGFET. With this type of construction, the drain current is pulling electrons into the channel and then inducing them to travel through the channel.

Figure C 7.7-1


S
G
D
INSULATING OXIDE LAYER
N
N
INSULATING OXIDE LAYER
SUBSTRATE (LIGHTLY DOPED P-TYPE)
NO N-TYPE DIFFUSED CHANNEL HERE

In the enhancement mode, the drain current is zero when V_{gs} is zero; hence, a normally open device, for actual operation V_{gs} must be slightly positive to turn the IGFET on. This voltage is referred to as the "threshold voltage."

As in other transistors, the enhancement-mode IGFET can be constructed using either N-type material or P-type material.

IGFET requires special handling precautions due to the thin insulating layer on the gate, and can be destroyed by any static on the IGFET's leads. The static charge on your fingers can damage the device. Manufacturers usually ship the devices with the three leads shorted together, to prevent static charges.

The symbol for an N-channel enhancement-mode IGFET is shown in Figure C 7.7-2.

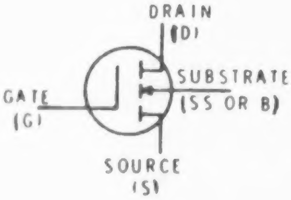

DRAIN
(D)
SUBSTRATE
(SS OR B)
GATE
(G)
SOURCE
(S)

Figure C 7.7-2

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ACTIVITY SHEET

C 7.8

1. In order for an enhancement-mode IGFET to conduct current, the V_{gs} must exceed a certain __________ voltage.

2. The depletion-mode IGFET is known as a normally __________ device.

3. When using an IGFET, care must be taken to insure that static charges do not damage the __________ layer, which is highly sensitive.

5. Only P-type IGFET's can be operated in the enhancement mode.

   A. True
   B. False

6. Only N-type IGFET's can be operated in the depletion mode.

   A. True
   B. False

7. If an IGFET is operating in the enhancement mode, a negative voltage must be applied to the gate to reduce the drain current to zero.

   A. True
   B. False

ACTIVITY SHEET KEY C 7.8

1. threshold
2. on
3. off
4. insulating
5. B
6. B
7. B

PROGRAM: ELECTRONICS

TASK: FIELD EFFECT TRANSISTORS

TASK # C 7.9

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

PERFORMANCE OBJECTIVE:

Examine the characteristics of the FET.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 80 out of 100 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance with 30 minutes and must score 80 out of 100 points or 80%, and all items marked with an asterisk (*) must be satisfactorily completed.

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ELECTRONICS

FIELD EFFECT TRANSISTORS

C 7.9

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
1.	Does circuit function correctly?	Y	N
*2.	Was circuit wired according to schematic?	Y	N
3.	Are connections correct?	Y	N
4.	Was necessary data recorded?	Y	N
*5.	Was correct equipment used?	Y	N
*6.	Was equipment used properly?	Y	N
*7.	Were safety precautions followed?	Y	N
8.	Was equipment returned to proper storage?	Y	N

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

SCORE _____

653

FIELD EFFECT TRANSISTOR

EXAM C 7.10

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on the characteristics of the FET transistor. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. Do not write on this test!!!!!! To master this exam you must answer 16 out of 20 items correctly, or 80%.

EXAM C 7.10

1. The part of the JFET that supports the electrodes is known as the __________.

   A. Gate
   B. Source
   C. Drain
   D. Substrate

2. The input impedance to a JFET is __________.

   A. High
   B. Low
   C. 400 Ohms
   D. 10,000 Ohms

3. In the JFET, the current is made to flow through the _______

   A. Channel
   B. Gate
   C. Enhancement Mode
   D. Depletion Mode

4. Decreasing the negative voltage applied to the gate of an N-type JFET will result in the drain current __________

   A. Remaining unchanged
   B. Increasing
   C. Decreasing

5. In an N-type JFET the majority carriers are __________

   A. Electrons
   B. Holes
   C. Substrate

6. The JFET is a __________ controlled device.

   A. Current-
   B. Voltage-
   C. Enhancement-
   D. Depletion-

EXAM C 7.10 CONT'D.

7. The controlling element in a JFET is the __________.

   A. Channel
   B. Source
   C. Drain
   D. Gate

8. In an operating P-type JFET, the majority carriers are __________.

   A. Gates
   B. Sources
   C. Drains
   D. Holes

9. The primary application of the JFET is using it as a/an __________.

   A. Switch
   B. Detector
   C. Amplifier
   D. Rectifier

10. When the V_{gs} causes the drain current to cease to flow, this is called the __________ voltage.

   A. Pinch-off
   B. Cut-off
   C. Drain
   D. Source

11. In an operating P-channel, JFET is biased so that its drain is __________ with respect to the source.

   A. Neutral
   B. Positive
   C. Negative
   D. Zero

12. If the arrow on the JFET symbol points in, the channel is made of __________-type material.

   A. N
   B. P

13. Only N-type material can be used for IGFET's if they are to operate in the enhancement mode.

   A. True
   B. False

14. The IGFET has a metallic gate that is insulated from its channel.

    A. True
    B. False

15. To cause an enhancement-mode IGFET to connect current, V_{gs} must exceed a certain __________ voltage.

    A. Source
    B. Drain
    C. Pinch-off
    D. Threshold

16. The input impedance of a MOSFET is _________ that of a JFET.

    A. Higher than
    B. Lower than
    C. Equal to

17. The type of MOSFET that works on the principle that an increase in V_{gs} results in an increase in I_d is a/an __________ type MOSFET.

    A. Depletion-
    B. Enhancement-
    C. N-
    D. P-

18. The type MOSFET that works on the principle that an increase in V_{gs} results in a decrease in I_d is a/an __________ type MOSFET.

    A. Depletion-
    B. Enhancement-
    C. N-
    D. P-

Use Figure C 7.10-1 for questions 19 and 20 (on next page)

19. On the positive alternation of the input signal the drain current will __________.

    A. Increase
    B. Decrease
    C. Remain the same

20. The output waveshape will be __________ with the input waveshape.

A. In phase
B. 180° out of phase
C. 90° out of phase

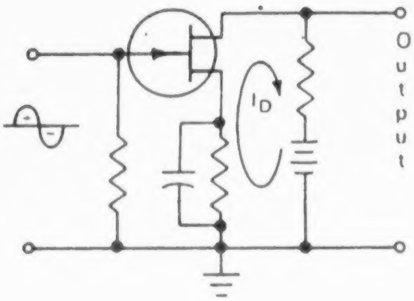


Figure C 7.10-1

EXAM KEY C 7.10

1. D
2. A
3. A
4. B
5. A
6. B
7. D
8. D
9. C
10. B
11. C
12. A
13. B
14. A
15. D
16. A
17. B
18. A
19. A
20. B

ELECTRONICS

ANALYZING SOLID STATE DEVICES

C 8: COMMON-SOURCE AMPLIFIER

TASK: From a schematic diagram analyze, construct, and troubleshoot a simple common-source amplifier.

PURPOSE: FET'S are used primarily as amplifying devices, just as bipolar transistors. Like bipolar transistors, FET's can be connected in three circuit configurations to be used as amplifiers. These three circuits are referred to as common-source, common-drain, and common-gate circuits, each having different characteristics. The three configurations apply to both JFET'S and IGET's. This task explores the common-source amplifier.

OBJECTIVE: Given the necessary resources and equipment, you will analyze, construct, and troubleshoot a simple common-source amplifier circuit. You must score at least 80% on both a written exam and laboratory performance checklist.

ESTIMATED CLASS TIME: 4 HOURS

COMMON-SOURCE AMPLIFIER

LEARNING STEPS

C 8

READ:	Information Sheet C 8.1, "The Common-Source Circuit."
READ:	Information on the common-source circuit from the following resource list.
COMPLETE:	Activity Sheet C 8.2, "The Common-Source Circuit." Contact your instructor.
COMPLETE:	Lab Performance on the common-source circuit. Contact your instructor.
COMPLETE:	Lab Performance CheckList C 8.3. Contact your instructor.
COMPLETE:	Exam C 8.4.

COMMON-SOURCE AMPLIFIER

RESOURCES

C 8

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1985). Fifth Edition.
2. Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). Fifth Edition.
3. Badrkhan and Lark, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984).
4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS (McGraw-Hill, 1984). Second Edition.
5. SEMICONDUCTOR DEVICES (Heath Company, 1982). Eighteenth Printing.

RECOMMENDED EQUIPMENT

0-24 VDC power supply
Volt - Ohmmeter or digital multimeter
Dual - trace oscilloscope
Various transistors
AF generator
RF generator

INFORMATION SHEET

C 8.1

THE COMMON-SOURCE AMPLIFIER CIRCUIT

The common-source amplifier is the most widely used of all FET circuit configurations. The circuit is comparable to the common-emitter circuit of the bipolar transistor. Refer to Figure C 8.1-1 for a typical common-source amplifier circuit.

With this circuit, the input is applied between the gate and source; the output is taken between the drain and source. This makes the source common to both the input and output signal.

Referring to Figure C 8.1-1, you note that the gate is negative to the source (the only current flowing through the R_G will be leakage current). The voltage across R_G is almost zero; therefore the full value of V_{GG} is effectively placed at the gate and source leads.

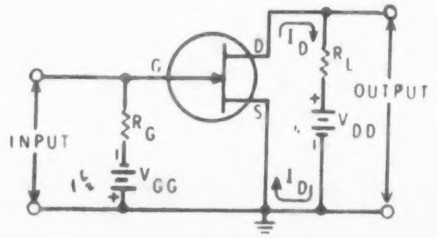


Figure C 8.1-1

The amount of V_{GG} applied will be the value of bias required to operate the FET in the pinch-off region. As in other transistor amplifiers, a resistor (R_L) must be placed between V_{DD} and the FET's drain lead. The combination of the FET and the load resistor (R_L) makes a voltage divider. A portion of V_{DD} will appear across the FET and the rest appears across the load resistor.

Under operating conditions, the FET will be controlled by the input voltage. This AC voltage alternately aids and opposes the V_{GG}; as this voltage varies, so will the drain current. This causes an AC voltage to be developed across R_L that is identical to the input but has a longer amplitude. This means the common-source amplifier has a large voltage gain.

The other feature the common-source amplifier has that makes it desirable is high input resistance, resulting in minimum loading on the input signal device.

The common-source amplifier is widely used in digital and computer applications, when a number of circuits must be connected to one source.

The output resistance of the common-source amplifier is lower than the input, but is classed as moderately high.

With the characteristics of high input resistance and high voltage gain, the common-source circuit has many uses as both an AC amplifier and a DC amplifier.

Both FET's and IGFET's (depletion or enhancement mode) can be used as common-source amplifiers.

ACTIVITY SHEET

C 8.2

1. For the common-source amplifier, the input signal is applied to the ________________.

2. The common-source amplifier is a ____________ controlled device.

3. The input resistance of the common-source amplifier is ________________.

4. Both N-type and P-type can be used as common-source amplifiers.

   A. True
   B. False

5. Only JFET's are suitable as common-source amplifiers.

   A. True
   B. False

6. Several common-source amplifiers may be connected in parallel without affecting the operation of the input device's operation.

   A. True
   B. False

7. In normal operation as a common-source amplifier, the gate-to-channel PN junction is forward biased.

   A. True
   B. False

ACTIVITY SHEET KEY C 8.2

1. Gate
2. Voltage
3. High
4. A
5. B
6. A
7. B

PROGRAM: ELECTRONICS

TASK: COMMON-SOURCE AMPLIFIER

TASK # C 8.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ________________________ EVALUATION SITE ____________

EVALUATOR'S NAME ______________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ____________

PERFORMANCE OBJECTIVE:

From a schematic diagram analyze, construct, and troubleshoot a simple common-source amplifier.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score 80 out of 100 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 80 out of 100 points or 80% ,and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

COMMON-SOURCE AMPLIFIER

C 8.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Does circuit function correctly?	Y N
*2.	Was circuit wired according to schematic?	Y N
3.	Are connections correct?	Y N
4.	Was necessary data recorded?	Y N
*5.	Was correct equipment used?	Y N
*6.	Was equipment used properly?	Y N
*7.	Were safety precautions followed?	Y N
8.	Was equipment returned to proper storage?	Y N

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

SCORE _____

COMMON-SOURCE AMPLIFIER

EXAM C 8.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on the simple common-source amplifier. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. Do not write on this test!!!! To master this exam you must answer 11 out of 13 items correctly, or 80%.

EXAM C 8.4

1. The controlling element in the common-source amplifier is the ______________.

   A. Gate
   B. Source
   C. Drain

2. The input resistance of the common-source amplifier ______________.

   A. Is low
   B. Is high
   C. Depends on V_{GG}
   D. Depends on V_{DD}

3. Only IGFET's are suitable for common-source amplifiers.

   A. True
   B. False

4. Both N-type and P-type FET's may be used as common-source amplifiers.

   A. True
   B. False

5. In the common-source amplifier, the input signal is applied to the ______________.

   A. Gate
   B. Source
   C. Drain

6. The common-source amplifier is a ______________ controlled device.

   A. Resistive-
   B. Current-
   C. Voltage-

EXAM C 8.4 CONT'D.

7. If the drain-to-source voltage applied to a FET is increased, the channel width will ___________.

   A. Increase
   B. Decrease
   C. Not change
   D. Go to zero

8. The output resistance of the common-source circuit is _____.

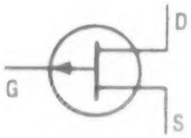
   A. High
   B. Low
   C. Moderately high
   D. Moderately low

9. The common-source circuit can amplify AC signals over a wide range of frequencies.

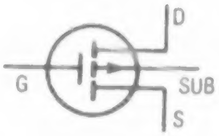
   A. True
   B. False

Refer to the figures below for Problems 10 through 13

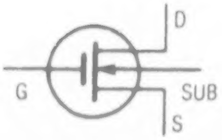
A.



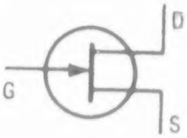
B.



C.



D.



10. Figure A represents the symbol of a(n) ____________.

   A. P-Channel MOSFET
   B. N-Channel MOSFET
   C. P-Channel FET
   D. N-Channel FET

EXAM C 8.4 CONT'D.

11. Figure B represents the symbol of a(n) ____________.

    A. N-Channel IGFET, Depletion Mode
    B. N-Channel IGFET, Enhancement Mode
    C. P-Channel IGFET, Depletion Mode
    D. P-Channel IGFET, Enhancement Mode

12. Figure C represents the symbol for a(n) ___________.

    A. N-Channel IGFET, Depletion Mode
    B. N-Channel IGFET, Enhancement Mode
    C. P-Channel IGFET, Depletion Mode
    D. P-Channel IGFET, Enhancement Mode

13. Figure D represents the symbol for a(n) ___________.

    A. N-Channel IGFET
    B. P-Channel IGFET
    C. N-Channel FET
    D. P-Channel FET

EXAM KEY C 8.4

1. A
2. B
3. B
4. A
5. A
6. C
7. C
8. C
9. A
10. C
11. D
12. A
13. C

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ELECTRONICS

ANALYZING SOLID STATE DEVICES

C 9: COMMON-DRAIN AMPLIFIER

TASK:	From a schematic diagram analyze, construct, and troubleshoot a simple common-drain amplifier.
PURPOSE:	FET's are used primarily as amplifying devices, just as bipolar transistors. Like bipolar transistors, FET's can be connected in three circuit configurations, to be used as amplifiers. These circuits are referred to as common-source, common-drain, and common-gate circuits, each having different characteristics. These three configurations apply to both JFET'S and IGFET'S. This task explores the common-drain amplifier.
OBJECTIVE:	Given the necessary resources and equipment, you will analyze, construct, and troubleshoot a common-drain amplifier. You must score at least 80% on both a written exam and laboratory performance checklist.

ESTIMATED CLASS TIME: 4 HOURS

COMMON-DRAIN AMPLIFIER

LEARNING STEPS

C 9

READ: Information Sheet C 9.1, "The Common-Drain Circuit."

READ: Information on the common-drain circuit from the following resource list.

COMPLETE: Activity Sheet C 9.2, "The Common-Drain Circuit."

COMPLETE: Lab Performance, the common-drain circuit. Contact your instructor.

COMPLETE: Lab Performance Checklist C 9.3.

COMPLETE: Exam C 9.4.

COMMON-DRAIN AMPLIFIER

RESOURCES

C 9

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1985). Fifth Edition.
2. Zbar and Malvino, BASIC ELECTRONICS(McGraw-Hill, 1983). Fifth Edition.
3. Badrkhan and Lark, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing Company, 1984.)
4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS (McGraw-Hill, 1984). Second Edition.
5. SEMICONDUCTOR DEVICES (Heath Company, 1982). Eighteenth Printing.

RECOMMENDED EQUIPMENT

0-24 VDC power supply
Volt Ohmmeter or digital multimeter
Dual- trace oscilloscope
Various transistors
AF generator
RF generator

INFORMATION SHEET

C 9.1

THE COMMON-DRAIN AMPLIFIER

The common-drain amplifier is much like the common-collector bipolar transistor. The basic common-drain amplifier is shown in Figure C 9.1-1.

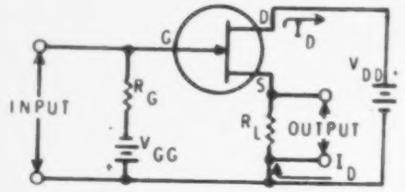


Figure C 9.1-1

The common-drain amplifier can be formed with P-type and N-type JFET's as well as enhancement-mode and depletion-mode IGFET's.

In the common-drain amplifier, the input signal is applied between the gate and drain, even though it appears to be applied between the gate and the source. The output is effectively developed between the drain and source, even though it appears to be taken from the source (across R_L). The output is taken between the drain and source because the voltage V_{DD} is effectively a short circuit to the input and output signals.

The common-drain amplifier is sometimes referred to as a "source follower." The voltage across R_L tends to track or follow the gate voltage; this results in the voltage across R_L being slightly less than the gate voltage. Therefore the voltage gain of a common-amplifier circuit will be less than one.

The common-drain amplifier has a very high input resistance and a very low output resistance. This makes it a circuit suitable for coupling a high resistance circuit to a low resistance circuit.

Both FET's and IGFET's (depletion or enhancement mode) can be used as common-drain amplifiers.

ACTIVITY SHEET

C 9.2

1. The common-drain amplifier is a ________________ controlled device.

2. The input resistance of a common-drain amplifier is ____________________.

3. The input resistance of a common-drain amplifier is ____________________ than the common-source amplifier.

4. In the common-drain amplifier, the input signal is applied between the __________ and __________.

5. Referring to Question 4, the output is taken from the __________ and __________.

6. If an IGFET is used as a common-drain amplifier, it must be in the enhancement mode.

   A. True
   B. False

7. With a low output resistance, common-drain amplifiers cannot be connected in parallel with the same input device.

   A. True
   B. False

ACTIVITY SHEET KEY C 9.2

1. Voltage
2. Very high
3. Higher
4. Gate and Source
5. Source and Drain
6. B
7. B

PROGRAM: ELECTRONICS

TASK: COMMON-DRAIN AMPLIFIER

TASK #: C 9.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE __________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT __________

PERFORMANCE OBJECTIVE:

From a schematic diagram analyze, construct, and troubleshoot a simple common-drain amplifier.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 80 out of 100 points , or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 and must score 80 out of 100 points or 80% and all items marked with an asterisk (*). These items must be satisfactorily completed.

ELECTRONICS

COMMON-DRAIN AMPLIFIER

C 9.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
1.	Does circuit function correctly?	Y	N
*2.	Was circuit wired according to schematic?	Y	N
3.	Are connections correct?	Y	N
4.	Was necessary data recorded?	Y	N
*5.	Was correct equipment used?	Y	N
*6.	Was equipment used properly?	Y	N
*7.	Were safety precautions followed?	Y	N
8.	Was equipment returned to proper storage?	Y	N

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

SCORE _____

COMMON-DRAIN AMPLIFIER

EXAM C 9.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on the common-drain amplifier. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. Do not write on this test!!!!! To master this exam you must answer 11 out of 13 items correctly, 80%.

EXAM C 9.4

1. In the common-drain amplifier, the input signal is applied between the ____________ and ____________.

   A. Gate, source
   B. Gate, drain
   C. Drain, source
   D. Drain, ground

2. Referring to Question 1, the output is taken between the ____________ and ____________.

   A. Gate, source
   B. Gate, drain
   C. Drain, source
   D. Drain, ground

3. The common-drain circuit is a __________ controlled device.

   A. Current-
   B. Voltage-
   C. Resistive-
   D. Power-

4. Only N-type FET's may be used as a common-drain amplifier.

   A. True
   B. False

5. The input resistance of the common-drain circuit is ______.

   A. Low
   B. Very low
   C. High
   D. Very high

6. The common-drain circuit is often referred to as the __________ __________ circuit.

   A. Drain-follower
   B. Gate-follower
   C. Source-follower
   D. FET-follower

EXAM C 9.4 CONT'D.

7. The output resistance of the common-drain circuit is _____.

A. High
B. Low
C. High or Low
D. Moderately low

8. The voltage gain of the common-drain circuit is __________.

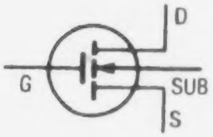
A. 10 to 100
B. 2 to 10
C. Over 100
D. Less than one

9. When compared to the common-source circuit, the input resistance of the common-drain current is ________________.

A. Higher
B. Lower
C. Same
D. Higher and Lower

Refer to the figures below for Questions 10 through 13

A.



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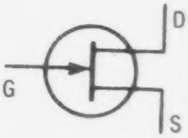
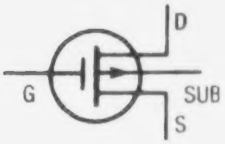
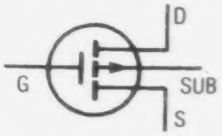


C.



D.



10. Figure A is the symbol for ____________.

A. N-channel IGFET, enhancement mode
B. N-channel IGFET, depletion mode
C. P-channel IGFET, enhancement mode
D. P-channel IGFET, depletion mode

11. Figure B is the symbol for ____________.

    A. N-channel IGFET, enhancement mode
    B. P-channel IGFET, enhancement mode
    C. N-channel JFET
    D. P-channel JFET

12. Figure C is the symbol for ____________.

    A. N-channel IGFET, enhancement mode
    B. P-channel IGFET, enhancement mode
    C. N-channel IGFET, depletion mode
    D. P-channel IGFET, depletion mode

13. Figure D is the symbol for ____________.

    A. N-channel IGFET, depletion mode
    B. P-channel IGFET, depletion mode
    C. N-channel IGFET, enhancement mode
    D. P-channel IGFET, enhancement mode

EXAM KEY C 9.4

1. A
2. C
3. B
4. B
5. D
6. C
7. B
8. D
9. A
10. A
11. C
12. D
13. B

ELECTRONICS

ANALYZING SOLID STATE DEVICES

C 10: COMMON-GATE AMPLIFIER

TASK:	From a schematic diagram, analyze, construct, and troubleshoot a simple common-gate amplifier.
PURPOSE:	FET's are used primarily as amplifying devices, just as bipolar transistors. Like bipolar transistors, FET's can be connected in three circuit configurations to be used as amplifiers. These circuits are referred to as common-source, common-drain, and common-gate, each having different characteristics. These three configurations apply to both JFET's and IGFET's. This task explores the common-gate amplifier.
OBJECTIVE:	Given the necessary resources and equipment, you will analyze, construct, and troubleshoot a common-gate amplifier circuit. You must score at least 80% on both a written exam and a laboratory performance checklist.

ESTIMATED CLASS TIME: 4 HOURS

COMMON-GATE AMPLIFIER

LEARNING STEPS

C 10

READ: Information Sheet, C 10.1, "The Common-Gate Circuit."

READ: Information on the common gate circuit from the following resource list.

COMPLETE: Activity Sheet C 10.2, "The Common Gate Circuit."

COMPLETE: Lab Performance, on the common-gate circuit. Contact your instructor.

COMPLETE: Lab Performance Checklist C 10.3. Contact your instructor.

COMPLETE: Exam C 10.3.

RESOURCES

C 10

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1985). Fifth Edition.
2. Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). Fifth Edition.
3. Badrkhan and Lark, ELECTRONICS: PRINCIPLES AND APPLICATIONS (South-Western Publishing, 1984).
4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS (McGraw-Hill, 1984). Second Edition.
5. SEMICONDUCTOR DEVICES (Heath Company, 1982). Eighteenth Printing.

RECOMMENDED EQUIPMENT

0 - 24 VDC power supply
Volt - ohmmeter or digital multimeter
Dual - trace oscilloscope
Various transistors
AF generator
RF generator

INFORMATION SHEET

C 10.1

THE COMMON-GATE CIRCUIT

Since the gate has primary control over the FET's conduction, and the base has primary control over the bipolar transistor's conduction, the circuit of each is similar.

The input signal is connected between the source and gate, while the output is taken between the drain and gate. The schematic for a common-gate circuit is shown in Figure C 10.1-1.

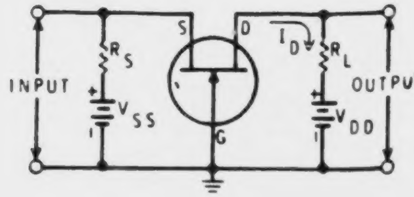


Figure C 10.1-1

The input-gate-to-source voltage is provided by V_{SS} and R_S, while the output-bias voltage is provided by V_{DD} and the load resistor R_L. The polarities of the voltages will depend on whether the FET is N-type or P-type, but it will have the same polarity as the common source circuit.

The input signal varies the gate to source voltage, causing the drain current to have the same variations. The drain current develops a voltage across R_L, this being the output voltage. This operation gives you a voltage gain; however, it is lower than the common-source circuit. The other important characteristics of the common-gate circuit are the input and output resistance. The input resistance is low and the output resistance is relatively high. This makes it a good circuit for matching a low resistance signal to a high resistance load.

Since the input signal and output signal do not share a common resistive component, the circuit is stable at high frequencies.

The common-gate circuit can be constructed using N-type, P-type, or IGFET's (depletion or enhancement mode).

ACTIVITY SHEET

C 10.2

1. The input signal to a common-gate circuit is applied between the __________ and _____________.

2. The output resistance of the common-gate circuit is _____________.

3. The output signal of the common-gate circuit appears between the __________ and ___________.

4. The input resistance of the common-gate circuit is _____________.

5. The element which has primary control over the drain current in the common-gate circuit is the _____________.

6. The battery polarities on the common-gate circuit will be the same regardless of the type of FET being used.

   A. True
   B. False

7. The output signal of a common-gate amplifier is developed across the ______________ _____________.

ACTIVITY SHEET KEY C 10.2

1. Source, gate
2. High
3. Drain, gate
4. Low
5. Source
6. B
7. Load resistor

PROGRAM: ELECTRONICS

TASK: COMMON-GATE AMPLIFIER

TASK # C 10.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE __________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT __________

PERFORMANCE OBJECTIVE:

From a schematic diagram, analyze, construct, and troubleshoot a simple common-gate amplifier.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 80 out of 100 points of 80% for mastery. Critical items are marked with an asterisk(*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 80 out of 100 points or 80%, and all items marked with an asterisk (*) must be satisfactorily completed.

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ELECTRONICS

COMMON-GATE AMPLIFIER

C 10.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Does the circuit function correctly?	Y N
*2.	Was the circuit wired according to the schematic?	Y N
3.	Are the connections correct?	Y N
4.	Was necessary data recorded?	Y N
*5.	Was correct equipment used?	Y N
*6.	Was equipment used properly?	Y N
*7.	Were safety precautions followed?	Y N
8.	Was equipment returned to proper storage?	Y N

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

SCORE _____

COMMON-GATE AMPLIFIER

EXAM C 10.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on the common-gate circuit. Each of the questions or incomplete statements is followed by several words, phrases, or a series of number. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. Do not write on this test!!!!! To master this exam you must answer 11 out of 13 items correctly, or 80%.

EXAM C 10.4

1. The common-gate circuit is well-suited for use as a high frequency amplifier.

   A. True
   B. False

2. The source-to-gate junction of common-gate amplifier must have a fixed bias applied to it.

   A. True
   B. False

3. A common-gate amplifier has a lower voltage gain than a common-source amplifier.

   A. True
   B. False

4. A common-gate amplifier has a lower input resistance when compared to the common-drain amplifier.

   A. True
   B. False

5. The controlling element in a common-gate amplifier is the ________________.

   A. Gate
   B. Drain
   C. Source
   D. Gate-drain junction

6. A common-gate circuit can be used to match a ____________ resistive input to a ______________ resistive.

   A. Low, low
   B. High, high
   C. High, low
   D. Low, high

7. The IGFET is also known as a MOSFET.

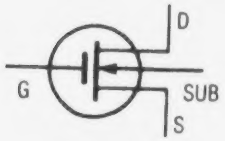
   A. True
   B. False

8. The noise level of a FET is ______________ when compared to a bipolar transistor.

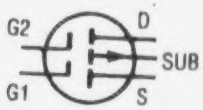
   A. Equal
   B. Higher
   C. Lower

Refer to the figures below for Questions 9 through 13

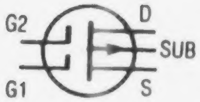
A.



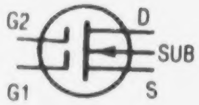
B.



C.



D.



9. Figure "A" represents the symbol for ______________.

   A. P-channel MOSFET, enhancement mode
   B. P-channel MOSFET, depletion mode
   C. N-channel MOSFET, depletion mode

10. Figure "B" represents the symbol for ______________.

   A. P-channel dual-Gate MOSFET, enhancement mode
   B. P-channel dual-Gate MOSFET, depletion mode
   C. N-channel dual-Gate MOSFET, enhancement mode
   D. N-channel dual-Gate MOSFET, depletion mode

11. Figure "C" represents the symbol for ____________.

    A. P-channel dual-Gate MOSFET, enhancement mode.
    B. P-channel dual-Gate MOSFET, depletion mode
    C. JFET
    D. None of the above

12. Figure "D" represents the symbol for _____________.

    A. N-channel MOSFET
    B. P-channel MOSFET
    C. N-channel dual-Gate MOSFET
    D. N-channel FET

13. Figure "E" represents the symbol for _____________.

    A. P-channel MOSFET, depletion mode
    B. N-channel MOSFET, depletion mode
    C. P-channel MOSFET, enhancement mode
    D. N-channel MOSFET, enhancement mode

EXAM KEY C 10.4

1. A
2. B
3. A
4. A
5. C
6. D
7. A
8. C
9. D
10. A
11. B
12. C
13. A

ELECTRONICS

ANALYZING SOLID STATE DEVICES

C 11: THYRISTOR

TASK:	From a schematic diagram, analyze, construct, and troubleshoot thyristor operations.
PURPOSE:	Thyristor is the term used to describe solid-state components which can be used as electronically controlled switches. The components have two conditions, either off (non-conducting) or on (conducting). They can be used to control AC or DC power. From previous studies you learned that bipolar transistors and field-effect transistors can be used as electronic switches. However, the thyristor family of components is more efficient and can handle more than bipolar transistors and FETS. Although several components fall in the thyristor family, in this task we will cover only those most widely used.
OBJECTIVE:	Given the necessary resources and information on several common thyristor components, you will analyze, construct, and troubleshoot these circuits. You must score at least 80% on a written exam and laboratory performance.

ESTIMATED TIME: 8 HOURS

THYRISTOR

LEARNING STEPS

C 11

READ: Information Sheet C 11.1, "Characteristics and Operation of the Unijunction Transistor."

READ: Information on the characteristics and operation of the unijunction transistor from the following resource list.

COMPLETE: Activity Sheet C 11.2, "Characteristics and Operation of the Unijunction Transistor."

READ: Information Sheet C 11.3, "Characteristics and Operation of the Silicon-Controlled Rectifier."

READ: Information on the characteristics and operation of the silicon-controlled rectifier from the following resource list.

COMPLETE: Activity Sheet C 11.4, "Characteristics and Operation of the Silicon-Controlled Rectifier."

READ: Information Sheet C 11.5, "Characteristics and Operation of the Diac and Triac."

READ: Information on the characteristics and operation of the diac and triac from the following resource list.

COMPLETE: Activity Sheet C 11.6, "Characteristics and Operation of the Diac and Triac."

COMPLETE: Lab performance on from a schematic diagram, analyze, construct, and troubleshoot thyristor operation. Contact your instructor.

COMPLETE: Lab Performance Checklist C 11.7. Contact your instructor.

COMPLETE: Exam C 11.8.

THYRISTOR

RESOURCES

C 11

1. Grob, Basic Electronics (McGraw-Hill, 1985). Fifth Edition.
2. Zbar and Malvino, Basic Electronics (McGraw-Hill, 1983). Fifth Edition.
3. Badrkhan and Lark, Electronics: Principals and Applications (South-Western Publishing, 1984).
4. Schuler, Electronics Principles and Applications (McGraw-Hill, 1984). Second Edition.
5. Semiconductor Devices (Heath Company, 1982. Eighteenth Printing.

RECOMMENDED EQUIPMENT

0 - 24 VDC power supply
Volt - Ohmeter or digital multimeter
Dual - trace oscilloscope
Various transistors: triacs, diacs, SCR's
AF generator
RF generator

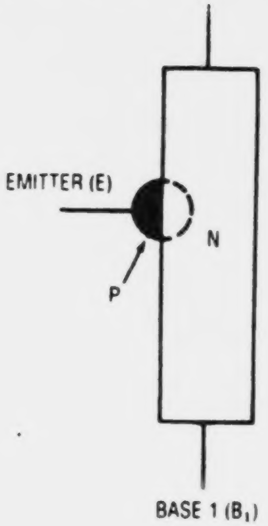
INFORMATION SHEET

C 11.1

CHARACTERISTICS AND OPERATION OF THE UNIJUNCTION TRANSISTOR

The unijunction transistor (UJT) is a special type of semiconductor device. Although called a transistor it has only one junction. Refer to Figure C 11.1-1 for the construction configuration of the UJT. The UJT has a bar of N-type material with a base lead at each end, called "bases." A pellet of P-type material is fused to the bar of N-type material. The three leads are identified as Base 1 (B_1), Base 2 (B_2), and Emitter (E). The N-type material is lightly doped, so the resistance between the two bases will be high, normally 5 to 10 kilo ohms.

Figure C 11.1-1



The symbol used to represent the UJT is shown in Figure C 11.1-2 with the equivalent circuit shown in Figure C 11.1-3.

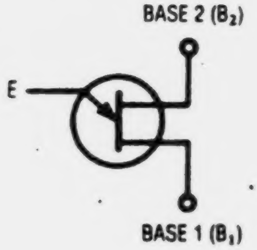


Figure C 11.1-2

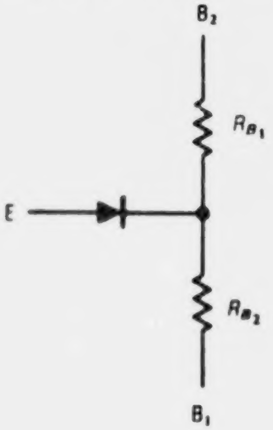
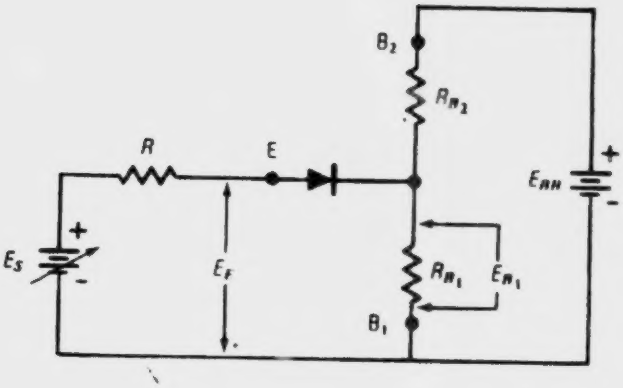


Figure C 11.1-3

INFORMATION SHEET C 11.1 CONT'D.

Figure C 11.1-4 shows the UJT being used in a circuit for normal operation. If the voltage E_S does not forward bias the diode, the supply voltage will be divided between R_{B1} and R_{B2}. The ratio of V and E_{BB} is called the "intrinsic stand off ratio." The "intrinsic stand off voltage" is represented by the Greek letter η (eta), and is expressed mathematically as $\eta = \frac{V_{B1}}{V_{BB}}$.

Figure C 11.1-4



The intrinsic stand-off ratio for each UJT will be supplied by the manufacturer. This value is typically between .5 and .8.

As the voltage applied to the emitter is increased, the UJT becomes forward-biased, resulting in high conductivity of the UJT. This voltage is referred to as a peak voltage (V_p). This voltage can be calculated by the formula $V_p = \eta V_{BB} + V_F$. V_F is the voltage necessary to turn on the diode.

The performance characteristic of the UJT is shown in Figure C 11.1-5 with a typical circuit shown in Figure C 11.1-6.

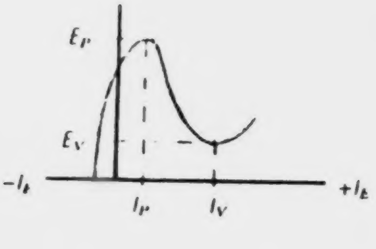


Figure C 11.1-5

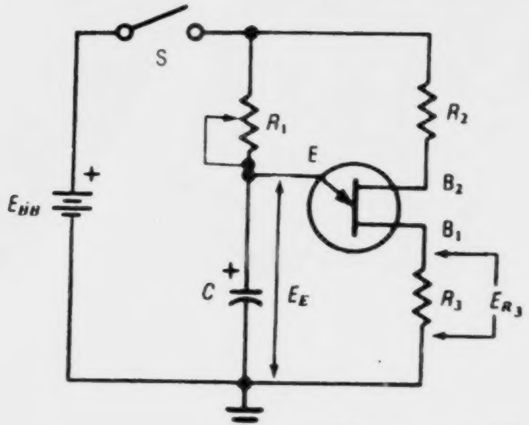


Figure C 11.1-6

UJT's can be produced with programmable characteristics; these devices are called PUT (Programmable Unijunction Transistor). Refer to Figure C 11.1-7 for the symbol of the PUT. The programmability of the PUT is the result of a different type of construction from the UJT. The PUT is constructed with four layers of semiconductor materials. A circuit using a PUT as an oscillator is shown in Figure C 11.1-8.

Figure C 11.1-7

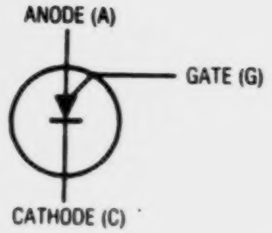
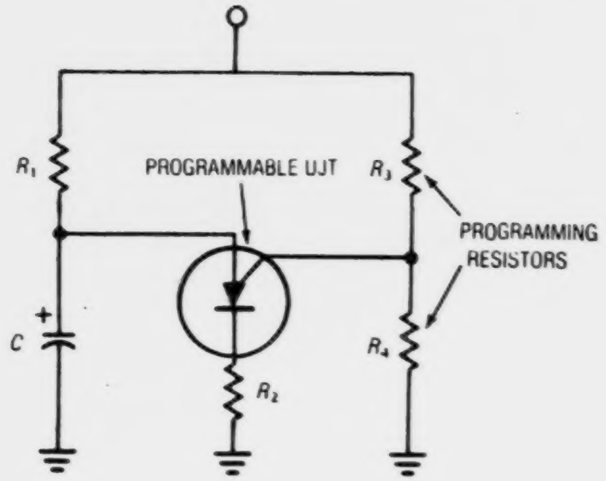

ANODE (A)
GATE (G)
CATHODE (C)

Figure C 11.1-8


R_1
PROGRAMMABLE UJT
R_3
PROGRAMMING RESISTORS
+
C
R_4
R_2

ACTIVITY SHEET

C 11.2

1. The lead attached to the UJT's P type is called the ________.
2. How many junctions does the UJT have? ___________
3. The equivalent UJT circuit can be represented by two resistors and a __________________.
4. The main feature of the PUT is that it is _________________.
5. The PUT has _____________________ leads.
6. The leads that are attached to the UJT's N-type are known as ____________________ and ____________________.
7. The amount of voltage required to turn on a UJT is known as its ____________________.
8. The ratio of R_{B1} and R_{B2} is called the ________________.
9. The PUT has ________________ PN junctions.
10. The design feature that gives the UJT its name is the fact that it has ______________________________.

ACTIVITY SHEET KEY C 11.2

1. emitter
2. one
3. diode
4. programmable
5. three
6. base 1, base 2
7. peak voltage
8. intrinsic stand-off voltage
9. three
10. one junction

INFORMATION SHEET

C 11.3

THE CHARACTERISTICS AND OPERATION OF THE SILICON-CONTROLLED RECTIFIER

The silicon-controlled rectifier (SCR) is the most popular member of the thyristor family. It is used most widely as an electronically controlled switch. The SCR is a semiconductor device that is constructed with four semiconductor regions and three leads. Refer to Figure C 11.3-1 for the construction configuration of the SCR and Figure C 11.3-2 for its symbol.

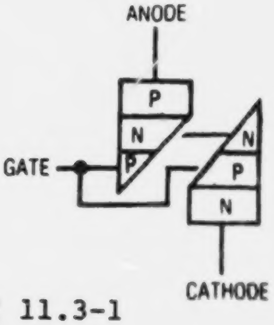


Figure C 11.3-1

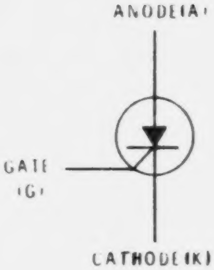


Figure C 11.3-2

The SCR is a rectifier that conducts current in one direction and does not have the ability to amplify signals.

The equivalent circuit and operation of the SCR are best shown by connecting a PNP and an NPN transistor. Refer to Figure C 11.3-3 for this circuit. From previous studies of transistors you know that with the gate open, the circuit will not conduct. Once the base is made positive with respect to the cathode, the circuit will switch to a conducting mode. One interesting principle of this circuit is that if the gate voltage is reduced to zero, the circuit will continue to conduct. The only way to cause current to cease would be to reduce or remove the anode to cathode voltage.

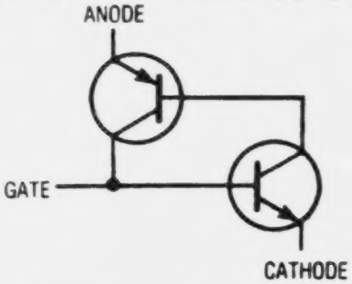


Figure C 11.3-3

As an electronic switch, the SCR surpasses the mechanical switch for several reasons: (1) it can safely switch high current, (2) it has no contacts that can bounce or stick, (3) there is no wear on the contacts.

ACTIVITY SHEET

C 11.4

1. The SCR can be used to control the amount of AC power applied to a load.

   A. True
   B. False

2. The SCR is a ________________ layer semiconductor device.

3. The method used to turn the SCR on is to apply ____________ current.

4. The leads to the SCR are referred to as the ______________ and _______________.

5. The SCR can be referred to as an __________________ switch.

6. The SCR has one stable state.

   A. True
   B. False

7. The minimum voltage required to turn the SCR on is called the ____________________.

ACTIVITY SHEET KEY C 11.4

1. A
2. four
3. gate
4. gate, anode, cathode
5. electronic
6. B
7. forward-breakdown voltage

INFORMATION SHEET

C 11.5

THE CHARACTERISTICS AND OPERATION OF THE DIAC AND TRIAC

The diac is a specially constructed diode that acts as an electronic switch. As a switch, it can provide bidirectional operation; that is, it can be operated with a positive or negative current.

The diac is a device constructed of three layers of semiconductor material. Referring to Figure C 11.5-1, you will note the construction is the same as a bipolar transistor, except there is no base lead. The fact that it has two leads makes the diac a diode. The symbols for the diac are shown in Figure C 11.5-2. The diac is also referred to as a "trigger diode" or "bidirectional trigger diode." Since the diac is a bidirectional switch, both PN junctions must be doped identically. This is necessary so the diac will respond uniformly in both directions.

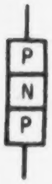


Figure C 11.5-1

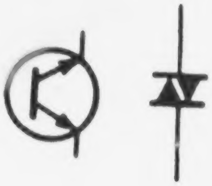


Figure C 11.5-2

Regardless of the direction of the current flow, one diode will be forward biased, the other reverse-biased. Therefore no current will flow until the applied voltage is sufficient to overcome the junction barriers. The voltage required to overcome the junction barrier is referred to as the breakdown voltage, E_{BO}. The breakdown voltage can be either positive or negative. Until the E_{BO} is reached, the diac will act as an open switch.

Another member of the thyristor family is the bidirectional triode thyristor, known as the "triac." The triac is another device that has widespread use as an electronic switch.

INFORMATION SHEET C 11.5 CONT'D.

The SCR makes an ideal switch for DC circuits, but additional components are needed if it is to be used in AC circuits. The triac is a device that can switch AC circuits without additional components. The construction configuration for the triac is shown in Figure C 11.5-3 with the symbol in Figure C 11.5-4.

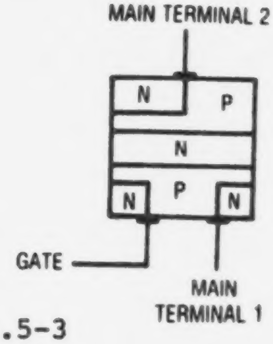


Figure C 11.5-3

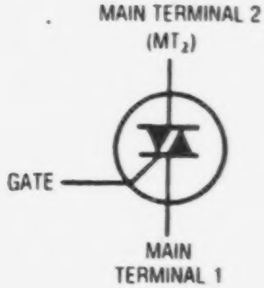


Figure C 11.5-4

A basic circuit showing the operation of a triac is represented by Figure C 11.5-5. The circuit is basically two SCR connected to act as one device. Referring to Figure C 11.5-5, note the triac will conduct when the gate trigger is positive or negative with respect to Terminal 1. Once the triac is conducting, it will continue to conduct, even with removal of the gate voltage. The voltage across the terminals must be reduced or removed to stop the current through the triac. Figure 11.5-6 shows the characteristic waves of the triac.

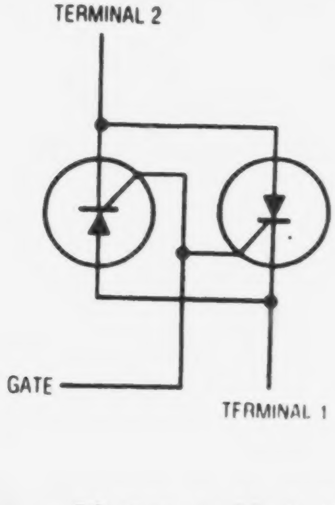


Figure C 11.5-5

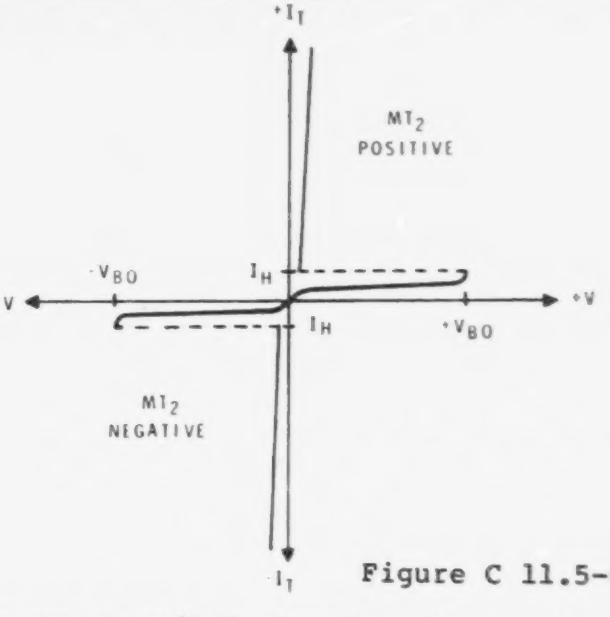


Figure C 11.5-6

The triac has many uses as a switch in the electronic field today, especially in microwave ovens.

712

ACTIVITY SHEET

C 11.6

1. The diac is a three-layer device, but has __________ leads.

2. The only use for the diac is to switch triacs.

   A. True
   B. False

3. The triac can be referred to as two ___________, which are connected in parallel but in opposite directions.

4. If a triac's gate current is increased, the breakdown voltage will be ______________________.

5. A diac can be turned on with only a positive voltage.

   A. True
   B. False

6. A triac can be turned on to conduct current in either direction.

   A. True
   B. False

7. Triacs should always be used instead of SCR's.

   A. True
   B. False

ACTIVITY SHEET KEY C 11.6

1. two
2. B
3. SCR's
4. B
5. B
6. A
7. B

PROGRAM: ELECTRONICS

TASK: THYRISTOR

TASK #: C 11.7

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ______________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ______________

PERFORMANCE OBJECTIVE:

From a schematic diagram, analyze, construct, and troubleshoot thyristor operations.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 80 out of 100 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 80 out of 100 points or 80% and all items marked with an asterisk (*) must be satisfactorily completed.

THYRISTOR

PERFORMANCE/PRODUCT CHECKLIST

C 11.7

CRITICAL ITEMS	ITEMS TO BE OBSERVED OR CHECKED	RATING YES/NO
1.	Does circuit function correctly?	Y N
*2.	Was circuit wired according to schematic?	Y N
3.	Are connections correct?	Y N
4.	Was necessary data recorded?	Y N
*5.	Was correct equipment used?	Y N
*6.	Was equipment used properly?	Y N
*7.	Were safety precautions followed?	Y N
8.	Was equipment returned to proper storage?	Y N

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY ____

SCORE _____

THYRISTORS

EXAM C 11.8

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information thryistors. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NCT WRITE ON THIS TEST!!! To master this exam you must answer 16 out of 20 items correctly or 80%.

EXAM 11.8

1. The PUT has ____________ junctions.

   A. one
   B. two
   C. three
   D. four

2. The PUT has ___________ leads.

   A. one
   B. two
   C. three
   D. four

3. The UJT has ____________ base leads.

   A. one
   B. two
   C. three
   D. four

4. Referring to the UJT, the term peak voltage refers to the device's _______________.

   A. breakdown voltage
   B. maximum usable voltage
   C. maximum allowable current
   D. voltage required to turn it on

5. A device that switches on and off according to voltages and bias applied, and is used as an oscillator or pulse generator is called a(n) __________.

   A. UJT
   B. diac
   C. triac
   D. SCR

6. The device that rectifies AC to DC according to timing of electrical impulse to gate and is used as a controllable rectifier is called a(n) __________.

   A. UJT
   B. diac
   C. triac
   D. SCR

7. In electronics, a device that switches on in either direction when the gate is triggered, and is also used to vary AC power, is known as a(n) _______________.

   A. UJT
   B. diac
   C. triac
   D. SCR

8. The SCR is a ________ layer semiconductor device.

   A. one-
   B. two-
   C. three-
   D. four-

9. The diac is a _____ layer semiconductor device.

   A. one-
   B. two-
   C. three-
   D. four-

10. The SCR has ________ stable state(s).

   A. one
   B. two
   C. three
   D. four

11. Referring to the SCR, the term forward-breakdown voltage means the _________________ voltage.

   A. maximum forward
   B. maximum reverse
   C. turn on
   D. breakdown

12. The device that switches on in either direction when voltage levels reach a breakdown voltage, used to provide triggering to AC control circuits is referred to as a(n) _________.

   A. UJT
   B. diac
   C. triac
   D. SCR

13. The triac can be turned on to conduct current in one direction only.

    A. True
    B. False

14. The diac can be turned on by either a positive or negative voltage.

    A. True
    B. False

15. The triac can be referred to as two ________ connected in parallel but in opposite directions.

    A. SCR's
    B. diac's
    C. UJT's
    D. PUT's

16. The symbol shown in C 11.8-1 represents a(n) ________.

    A. UJT
    B. diac
    C. triac
    D. SCR

17. The symbol shown in C 11.8-2 represents a(n) ________.

    A. UJT
    B. diac
    C. triac
    D. SCR

18. The symbol shown in C 11.8-3 represents a(n) ________.

    A. UJT
    B. diac
    C. triac
    D. SCR

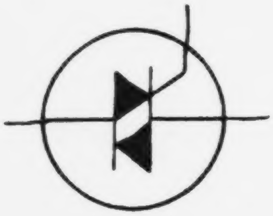


Figure C 11.8-1

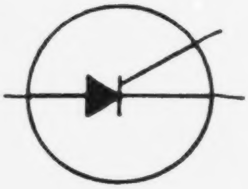


Figure C 11.8-2

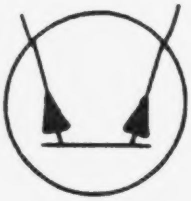


Figure C 11.8-3

Refer to Figure C 11.8-4 for questions 19 and 20.

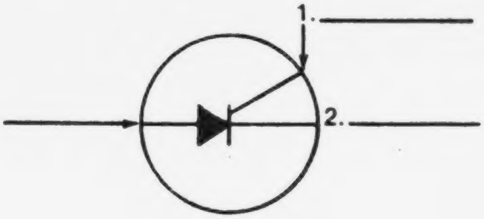


Figure C 11.8-4

19. The lead labelled 1 is represented by the letter:

    A. G
    B. K
    C. A
    D. B

20. The lead labelled 2 is represented by the letter:

    A. G
    B. K
    C. A
    D. B

EXAM KEY C 11.8

1. C
2. C
3. B
4. D
5. A
6. D
7. C
8. D
9. C
10. B
11. C
12. B
13. B
14. A
15. A
16. C
17. D
18. B
19. A
20. B

ELECTRONICS

ANALYZING SOLID STATE DEVICES

C 12: OPERATIONAL AMPLIFIER

TASK: From a schematic diagram analyze, construct, and troubleshoot an integrated-circuit operational amplifier.

PURPOSE: The integrated circuit (IC) plays an important role in the electronics industry. The IC is a single package, consisting of a complete circuit. Some of the advantages of the IC are its small size and reliability; it consumes less power, and costs less than conventional circuits. The disadvantages of the IC are that it cannot handle large currents or voltages, has limited power dissipation ratings, and cannot be repaired. The advantages outweigh the disadvantages. The IC can be put into two general categories: digital IC's and linear IC's. The linear IC provides an output proportional to the input. For this task we will examine the linear IC. This device is often referred to as the operational amplifier (OP amplifier).

OBJECTIVE: Given the necessary resources and information on the integrated-circuit operational amplifier, you will analyze, construct, and troubleshoot the integrated-circuit operational amplifier. You must score at least 80% on a written exam and laboratory performance.

ESTIMATED CLASS TIME: 10 HOURS

OPERATIONAL AMPLIFIER

LEARNING STEPS

C 12

READ: Information Sheet C 12.1, "The Characteristics and Operation of the Open-Loop Operational Amplifier."

READ: Information on the characteristics and operation of the open-loop operational amplifier from the following resource list.

COMPLETE: Activity Sheet C 12.2, "The Characteristics and Operation of the Open-Loop Operational Amplifier."

READ: Information Sheet C 12.3, "The Construction and Operation of the Closed-Loop Operational Amplifier."

READ: Information on the construction and operation of the closed-loop operational amplifier from the following resource list.

COMPLETE: Activity Sheet C 12.4, "The Construction and Operation of the Closed-Loop Operational Amplifier."

COMPLETE: Lab Performance on the integrated-circuit operational amplifier. Contact your instructor.

COMPLETE: Lab Performance Checklist C 12.5. Contact your instructor.

COMPLETE: Exam C 12.6.

OPERATIONAL AMPLIFIER

RESOURCES

C 12

1. Grob, Basic Electronics (McGraw-Hill, 1985). Fifth Edition.
2. Zbar and Malvino, Basic Electronics (McGraw-Hill, 1983). Fifth Edition.
3. Badrkhan and Lark, Electronics: Principals and Applications (SouthWestern Publishing, 1984).
4. Schuler, Electronics Principals and Applications (McGraw-Hill, 1984). Second Edition.
5. Semiconductor Devices (Heath Company, 1982). Eighteenth Printing.

RECOMMENDED EQUIPMENT

0 - 24 VDC power supply
Volt - Ohmmeter or digital multimeter
Dual - trace oscilloscope
Various transistors
AF generator
RF generator

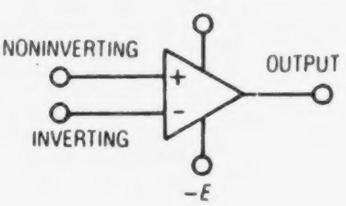
INFORMATION SHEET

C 12.1

THE CONSTRUCTION AND OPERATION OF THE OPEN-LOOP OP AMP

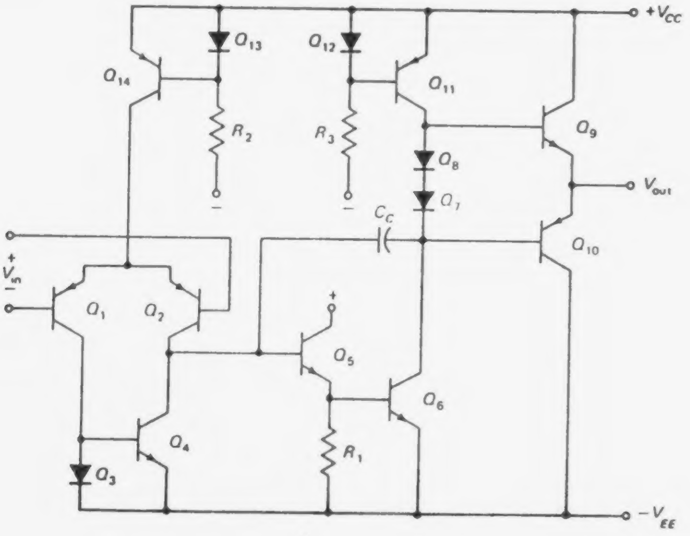
OP amps are the most widely used type of linear IC. The schematic symbol for the OP amp is shown in Figure C 12.1-1. The circuit has two inputs and one output. One input is referred to as the plus (+) or non-inverting input. The other is referred to as the minus (-) or inverting input. Signals applied to the (+) input will appear at the output exactly as the input. That is, if the input goes positive, the output will be positive. When a signal is applied to the (-) input, the output will be opposite to that of the input. This feature makes this device more versatile.

Figure C 12.1-1



OP amps can be used to amplify both AC and DC signals, with a frequency range of 0 to approximately 1 MHz. A schematic for the typical OP amp is shown in Figure C 12.1-2. Note that the components used in the circuit are included in the IC package. OP amps can be classified in two broad circuit configurations: open-loop and closed-loop. This information sheet will examine the open-loop circuit.

Figure C 12.1-2



INFORMATION SHEET C 12.1 CONT'D.

The OP amp is packaged in at least three ways to suit various applications. The packages are the DIP (dual in-line package) represented by Figure C 12.1-3. The same components can be packaged in the metal can-type enclosure, shown in Figure C 12.1-4. It is even available as minidips, shown in Figure C 12.1-5.

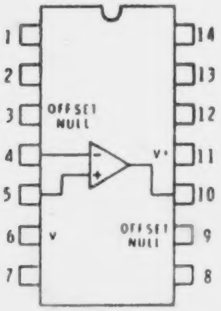

1
2
3
4
5
6
7
14
13
12
11
10
9
8
OFFSET NULL
V+
V
OFFSET NULL
-
+

Figure C 12.1-3

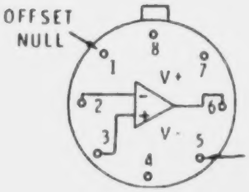

OFFSET NULL
8
7
1
V+
2
6
3
V-
5
4
-
+

Figure C 12.1-4

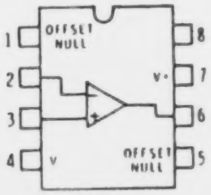

1
2
3
4
8
7
6
5
OFFSET NULL
V+
V
OFFSET NULL
-
+

Figure C 12.1-5

Since the open-loop OP amp is a linear device, its largest application is in electronic analog applications. It is also suitable for test equipment and communications equipment.

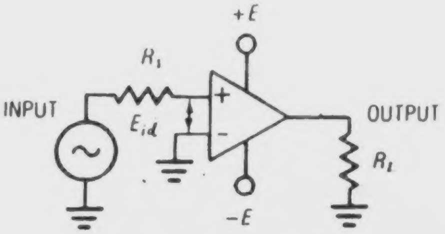
The open-loop OP amp operates over a range of voltages (these are supplied by the manufacturer). They have a high input resistance and a low output resistance. Several types have gains as high as several thousands.

The gain of the open-loop amp is the ratio of the output voltage to the differential input:

$$\text{Avol} = \frac{E_o}{E_{id}}$$

The circuit for the open-loop OP amp is shown in Figure C 12.1-6. This circuit is a straight-forward amplifier with the input moving through the amplifier to the output. No feedback or stabilizing voltages are used. This is the basis for describing this circuit as an open-loop OP amp.

Figure C 12.1-6


+E
R_1
INPUT
E_{id}
+
-
OUTPUT
R_L
-E

ACTIVITY SHEET

C 12.2

1. The open-loop OP amp is a digital device.

   A. True
   B. False

2. The gain of the open-loop OP amp is determined by the manufacturer.

   A. True
   B. False

3. The open-loop OP amp is packaged in three configurations. They are ______________, _______________, and _____________.

4. All open-loop OP amps operate only with a voltage supply of voltage of 5 volts.

   A. True
   B. False

5. The open-loop OP amp has a ______ input resistance.

   A. high
   B. low

6. The output resistance of the open-loop OP amp is:

   A. high
   B. low

7. In an open-loop OP amp circuit with a differential input of 2 mv and an output of 2 v, the gain would be _________.

ACTIVITY SHEET KEY C 12.2

1. B
2. A
3. dip, mini-dip, metal can
4. B
5. A
6. B
7. 1000

INFORMATION SHEET

C 12.3

THE CONSTRUCTION AND OPERATION OF THE CLOSED-LOOP OP AMP

OP amps are the most widely used type of linear IC's. The schematic symbol for the OP amp is shown in Figure C 12.3-1. The circuit has two inputs and one output. One input is referred to as the plus (+) or non-inverting input. The other is referred to as the minus (-) or inverting input. Signals applied to the (+) input will appear at the output exactly as the input. That is, if the input goes positive, the output will be positive. When a signal is applied to the (-) input, the output will be opposite to that of the input. This feature makes this device more versatile.

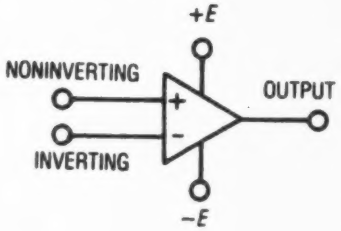
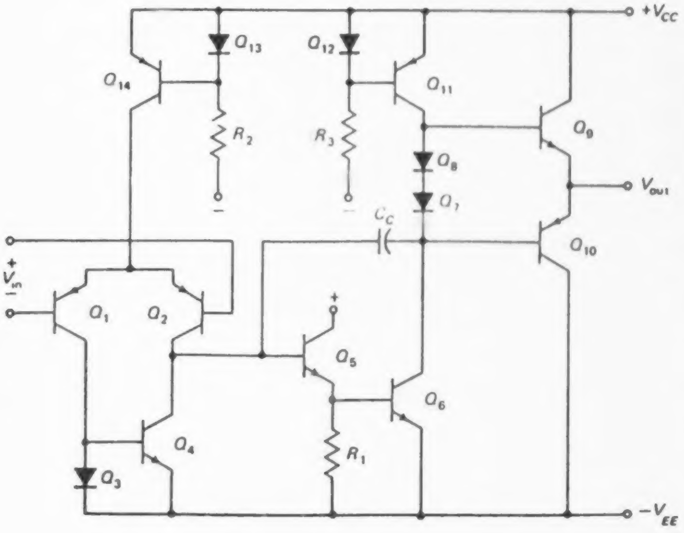

+E
NONINVERTING
+
-
INVERTING
OUTPUT
-E

Figure C 12.3-1

OP amps can be used to amplify both AC and DC signals, with a frequency range of 0 to approximately 1 MHz. A schematic for the typical OP amp is shown in Figure C 12.3-2. Note that the components used in the circuit are included in the IC package.

Figure C 12.3-2


+V_CC
Q_13
Q_12
Q_14
Q_11
R_2
R_3
Q_9
Q_8
V_out
Q_7
C_C
Q_10
+
V_in
-
Q_1
Q_2
+
Q_5
Q_6
Q_4
R_1
Q_3
-V_EE

INFORMATION SHEET C 12.3 CONT'D.

The OP amp is packaged in at least three ways to suit various applications. The packages are the DIP (dual in-line package) represented by Figure C 12.3-3. The same components can be packaged in the metal can-type enclosure, shown in Figure C 12.3-4. It is even available as mini-dips shown in Figure C 12.3-5.

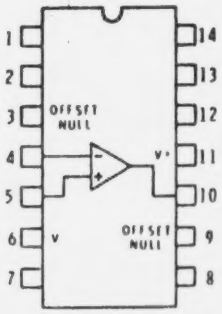

1
2
3
4
5
6
7
14
13
12
11
10
9
8
OFFSET NULL
V+
V
OFFSET NULL

Figure C 12.3-3

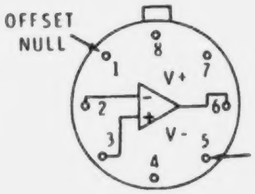

OFFSET NULL
8
7
1
V+
2
6
3
V-
5
4

Figure C 12.3-4

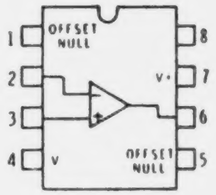
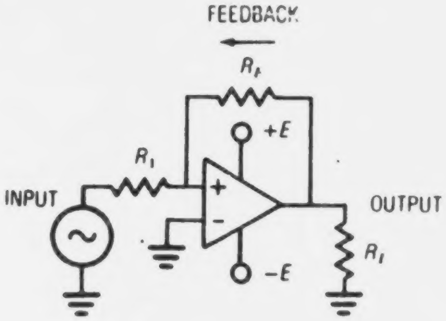

1
2
3
4
OFFSET NULL
8
V+
7
6
V
OFFSET NULL
5

Figure C 12.3-5

This information sheet will deal with the closed-loop OP amp. The closed-loop OP amp is shown in Figure C 12.3-6. This circuit is the same as the open-loop circuit, except the closed-loop circuit has the added connection of a feedback circuit. As you know, the feedback circuit puts a portion of the output signal back to the input. With proper feedback, the circuit can be made to oscillate. Feedback can be positive or negative; this circuit shows positive feedback.

Figure C 12.3-6


FEEDBACK
R_f
+E
R_1
INPUT
+
−
OUTPUT
R_l
−E

INFORMATION SHEET C 12.3 CONT'D.

If the feedback is connected to the inverting input, the feedback will be negative because the feedback signal is 180° out of phase with the input. This lowers the overall gain of the circuit, but it also reduces the distortion of the circuit.

The voltage gain of the closed-loop OP amp circuit is the ratio of the output to input voltage. This can be calculated by the following formula:

$$A_{vol} = \frac{E_o}{E_{10}}$$

OP amps, both open-loop and closed-loop, are used in many applications including medical, military, commercial, and industrial instruments. They are useful in these applications because of their sensitivity and the ability to amplify both AC and DC signals.

ACTIVITY SHEET

C 12.4

1. The main effect of a positive-feedback loop will be to ___________ the gain of the circuit.

   A. raise
   B. lower

2. A linear circuit provides an output that is _______________ to its input.

3. The OP amp is a ______________________ device.

   A. linear
   B. digital

4. The eight-pin dip package is referred to as _______________.

5. The input resistance of the closed-loop OP amp is _________.

6. The main effect of a negative-feedback loop will be to raise or lower the gain of the circuit.

   A. True
   B. False

7. The input voltage to a closed-loop OP amp is 300 μv, the output is 6 v. The gain of the circuit is ________________.

ACTIVITY SHEET KEY C 12.4

1. A
2. proportional
3. A
4. mini-dip
5. high
6. lower
7. 20,000

PROGRAM: ELECTRONICS

TASK: OPERATIONAL AMPLIFIER

TASK # C 12.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ________________

EVALUATOR'S NAME ________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ________________

PERFORMANCE OBJECTIVE:

From a schematic diagram analyze, construct, and troubleshoot an integrated-circuit operational amplifier.

DIRECTION TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 80 out of 100 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 80 out of 100 points or 80%, and all items marked with an asterisk (*) must be satisfactorily completed.

OPERATIONAL AMPLIFIER

PERFORMANCE/PRODUCT CHECKLIST

C 12.5

CRITICAL ITEMS	ITEMS TO BE OBSERVED OR CHECKED	RATING YES/NO	
1.	Does circuit function correctly?	Y	N
*2.	Was circuit wired according to schematic?	Y	N
3.	Are connections correct?	Y	N
4.	Was necessary data recorded?	Y	N
*5.	Was correct equipment used?	Y	N
*6.	Was equipment used properly?	Y	N
*7.	Were safety precautions followed?	Y	N
8.	Was equipment returned to proper storage?	Y	N

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

SCORE _____

736

OPERATIONAL AMPLIFIER

EXAM C 12.6

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on the integrated-circuit operational amplifier. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the questions or completes the statements correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer 13 out of 16 items correctly, or 80%.

EXAM C 12.6

1. The open-loop OP amp is a linear device.

   A. True
   B. False

2. The closed-loop OP amp will operate with a wide range of supply voltage.

   A. True
   B. False

3. A circuit using an OP amp has a low input resistance.

   A. True
   B. False

4. OP amps are packaged only in 16-pin dip.

   A. True
   B. False

5. The main effect of positive feedback is to ____________ the gain of the OP amp circuit.

   A. Increase
   B. Decrease

6. The purpose of the offset null terminals on the OP amp is to null the amplifier.

   A. True
   B. False

7. For an open-loop OP amp with a differential input of 3 mv and a gain of 10,000, the output voltage will be ________.

   A. 333.3V
   B. 30V
   C. 30,000V
   D. .33V

8. The closed-loop OP amp has a low output resistance.

   A. True
   B. False

EXAM C 12.6 CONT'D.

9. The main effect of negative feedback is to _______________ the gain of the OP amp circuit.

   A. raise
   B. lower
   C. stabilize

10. In addition to lowering the gain, negative feedback _______________ the bandwidth.

   A. decreases
   B. increases

11. The gain listed on the OP amp specification chart is the __________ gain.

   A. open-loop
   B. closed-loop
   C. positive-feedback
   D. negative-feedback

Refer to Figure C 12.6-1 for questions 12 through 14.

12. Which section of the amplifier is operating as an emitter follower ________.

   A. 1
   B. 2
   C. 3

13. A signal is applied to the inverting-input terminal. What is the relationship between the output signal and the input signal?

   A. in phase
   B. 90o out of phase
   C. 180o out of phase

14. The output of the amplifier is ___________.

   A. differential
   B. single-ended
   C. high resistance

15. The OP amp can be used as an active low-pass filter.

   A. True
   B. False

16. The OP amp can be used as an active band-pass filter.

    A. True
    B. False

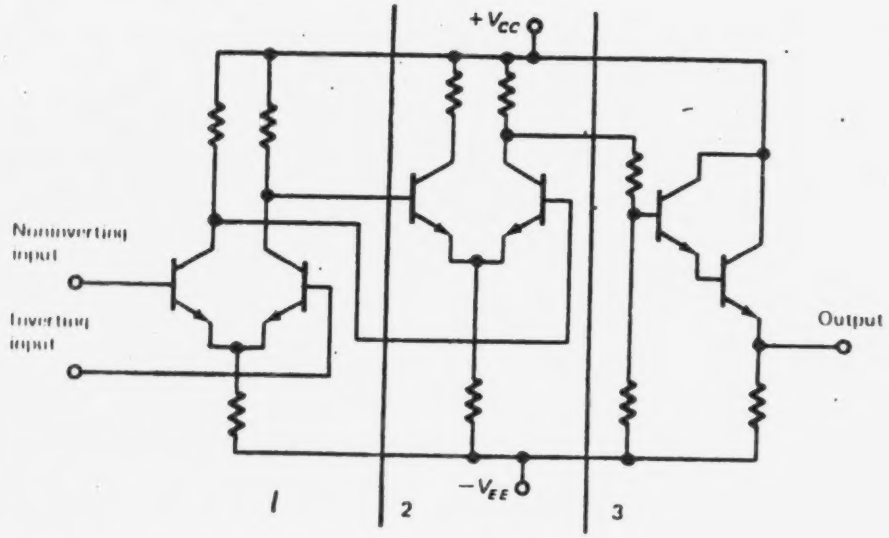

$+V_{CC}$
Noninverting input
Inverting input
Output
$-V_{EE}$
1
2
3

Figure C 12.6-1

EXAM KEY C 12.6

1. A
2. A
3. B
4. B
5. A
6. A
7. B
8. A
9. B
10. A
11. A
12. C
13. C
14. B
15. A
16. A

ELECTRONICS

ANALYZING SOLID STATE DEVICES

C 13: OPTOELECTRONIC DEVICES

TASK: From a schematic diagram analyze, construct, and troubleshoot optoelectronic devices.

PURPOSE: "Optoelectronic" is the term used to identify a group of solid-state devices, divided into two groups: light-sensitive devices and light-emitting devices. In this task you will examine several components from both groups. It will be necessary for you to become familiar with terms, definitions and units of measurements used in this field of electronics.

OBJECTIVE: Given the necessary resources and schematics of various optoelectronic devices, you will construct and troubleshoot these circuits. You must score at least 80% on a written test and laboratory performances.

ESTIMATED CLASS TIME: 8 HOURS

OPTOELECTRONIC DEVICES

LEARNING STEPS

C 13

READ: Information Sheet C 13.1, "Construction and Operation of Light-Sensitive Devices."

READ: Information on the construction and operation of light-sensitive devices from the following resource list.

COMPLETE: Activity Sheet C 13.2, "Construction and Operation of Light-Sensitive Devices."

READ: Information Sheet C 13.3, "Construction and Operation of Light-Emitting Devices"

READ: Information on the construction and operation of light-emitting devices.

COMPLETE: Activity Sheet D 13.4, "Construction and Operation of Light-Emitting Devices."

COMPLETE: Lab Performance on the construction and operation of optoelectronic devices. Contact your instructor.

COMPLETE: Lab Performance Checklist C 13.5. Contact your instructor.

COMPLETE: Exam C 13.6.

OPTOELECTRONIC DEVICES

RESOURCES

C 13

1. Grob, Basic Electronics (McGraw-Hill, 1985). Fifth Edition.
2. Zbar and Malvino, Basic Electronics (McGraw-Hill, 1983). Fifth Edition.
3. Badrkhan and Lark, Electronics: Principles and Applications (SouthWestern Publishing, 1984).
4. Schuler, Electronics Principles and Applications (McGraw-Hill, 1984). Second Edition.
5. Semiconductor Devices (Heath Company, 1982). Eighteenth Printing.

RECOMMENDED EQUIPMENT

0-24 VDC power supply
Volt - Ohmmeter or digital multimeter
Dual - trace oscilloscope
Various transistors
AF generator
RF generator
IC OP amps

744

INFORMATION SHEET

C 13.1

CONSTRUCTION AND OPERATION OF LIGHT-SENSITIVE DEVICES

Most of the optoelectronic devices used in the electronic field today are basically light-sensitive devices. These devices respond to light by generating a voltage or changing their internal resistance.

The photoconductive cell (photo cell) is the oldest of the optoelectronic devices. Basically it is a light-sensitive resistor. The resistance lowers with an increase in light and decreases with a decrease in light. This change in resistance is non-linear. The symbols for a photoconductive cell are shown in Figure C 13.1-1.

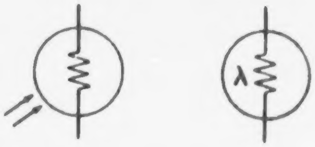


Figure C 13.1-1

Two advantages of the photocell is that it can withstand voltages up to 300 v DC and be used with AC or DC. The main disadvantage is that it responds slowly to changes in illuminations.

The photo cell is often used as an intrusion detector and automatic door opener by sensing the absence or presence of light.

The photovoltaic cell is a device that responds to light by converting it to electrical energy. It is commonly used as a solar cell to convert solar energy to electrical energy. The photovoltaic cell is constructed from semiconductor materials to form a PN junction. This construction is shown in Figure C 13.1-2. These cells need a large surface in order to collect as much light as possible.

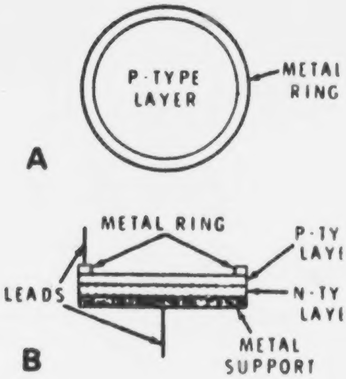


Figure C 13.1-2

One of the important uses of the device today is on spacecraft to supply electrical power to the equipment. Other uses for this device are in photographic light meters and in projectors to reproduce the sound track. The schematic symbol for the photovoltaic cell is shown in Figure C 13.1-3.

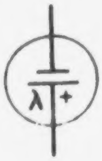


Figure C 13.1-3

Another light-sensitive device is the photodiode. It is constructed like the photovoltaic cell in that it uses a PN junction. However, instead of using the junction to generate a voltage, it uses it as a light-sensitive resistor. The symbol for the photodiode is shown in Figure C 13.1-4, with a typical circuit shown in Figure C 13.1-5.

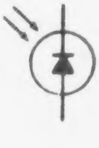


Figure C 13.1-4

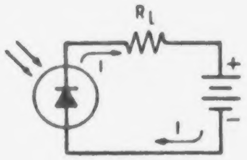


Figure C 13.1-5

The photodiode has an advantage over the photoconductor cell discussed earlier in this information sheet. The photodiode operates much faster than any other photosensitive device. The disadvantage with the photodiode is that, since it is a semiconductor device, it has low output current.

Another, important light-sensitive device is the phototransistor. It also is a PN-junction device, However, it has two junctions, like an ordinary transistor. The symbol for the phototransistor is shown in Figure C 13.1-6. To understand this device, a study of Figure C 13.1-7 is necessary. As you can see this circuit is a transistor with a photodiode connected across the base and collector. Thus the current in the transistor is controlled by the light striking the photodiode. The main advantage the phototransistor has over the photodiode is the amount of current the device can handle. The main disadvantage is that it responds slower than the photodiode.

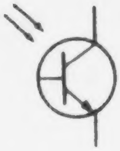


Figure C 13.1-6

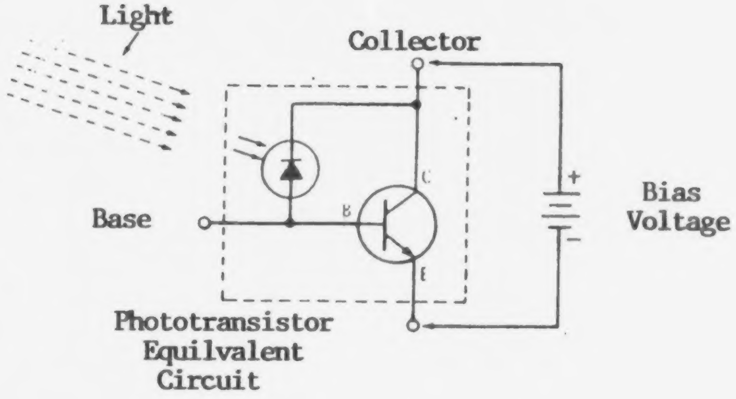


Figure C 13.1-7

747

ACTIVITY SHEET

C 13.2

1. Light should be considered to be electromagnetic radiation that is visible to the human eye.

   A. True
   B. False

2. Ultraviolet rays are visible to the human eye.

   A. True
   B. False

3. Infrared rays are visible to the human eye.

   A. True
   B. False

4. The light spectrum extends from 300 GHz to 300,000,000 GHz.

   A. True
   B. False

5. Photovoltaic cells may be connected in ________________ to produce a higher voltage.

6. The resistance of a photo cell increases as the amount of light is ________________.

7. The solar cell is the same as a ________________ cell.

8. The photo cell is basically a light-sensitive ________________.

9. The phototransistor has a higher ________________ output than the photodiode.

10. In a proper photo cell circuit the highest current flows during the dark condition.

    A. True
    B. False

743

ACTIVITY SHEET KEY C 13.2

1. A
2. B
3. B
4. A
5. series
6. decreased
7. photovoltaic
8. resistor
9. current
10. B

INFORMATION SHEET

C 13.3

CONSTRUCTION AND OPERATION OF LIGHT EMITTING DEVICES

Light-emitting devices are components that turn electrical current into visible light. For many years the most popular devices we had were the incandescent and neon lamps. In recent years a new light-emitting device was developed, called the light-emitting diode (LED). One advantage is that it has unlimited life expectancy. The symbol for the LED is shown in Figure C 13.3-1.

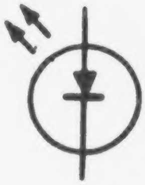


Figure C 13.3-1

LED's are PN diodes made from semiconductor materials that promote combination or recombination of electrons and holes to form protons. The material used to construct the LED is not silicon or germanium. Rather it is gallium-arsenide, gallium-arsenide phosphide, or gallium-phosphide. The type of semiconductor material used will determine the frequency of the light emitted. Depending on the frequency of the light it will appear blue, yellow, red, or green.

The operating principle of the LED is shown in Figure C 13.3-2, with the construction shown in C 13.3-3.

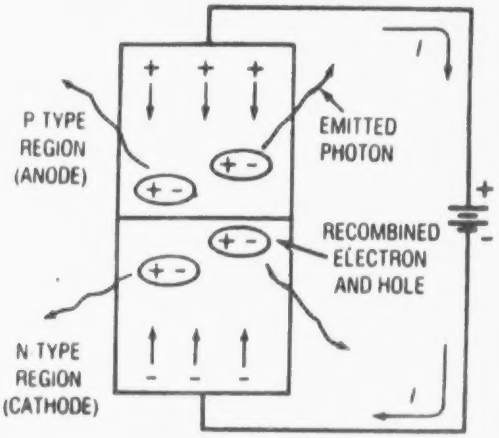

P TYPE REGION (ANODE)
EMITTED PHOTON
RECOMBINED ELECTRON AND HOLE
N TYPE REGION (CATHODE)
+
-
I
I

Figure C 13.3-2

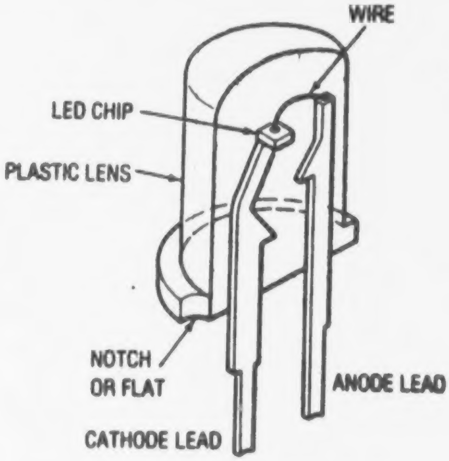

WIRE
LED CHIP
PLASTIC LENS
NOTCH OR FLAT
ANODE LEAD
CATHODE LEAD

Figure C 13.3-3

The intensity of the light produced by the LED will vary with the color. Red light has the greatest use in indicator lamps and numeric displays for a wide range of instruments.

The LED gives off light; the LCD (Liquid Crystal Display) controls light. The LCD reflects part of the light while other parts absorb light. The most widely used LCD today is the field-effect LCD. This device produces black letters or numbers on a silvery background. The LCD has extremely low power consumption.

Figure C 13.3-4 shows the construction of the LCD with an AC signal applied to drive segment e.

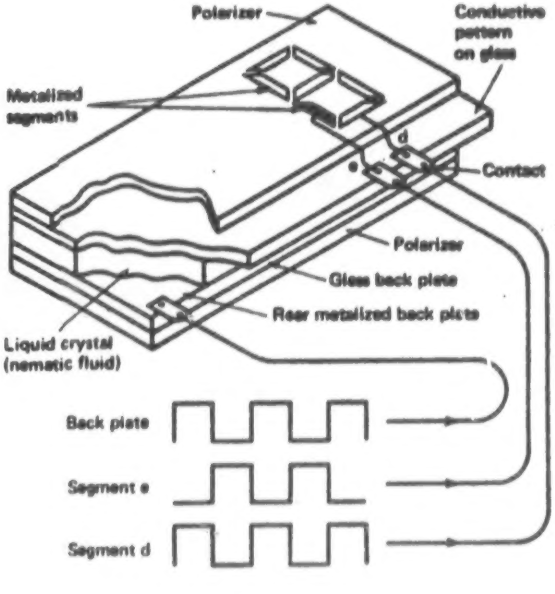

Polarizer
Conductive pattern on glass
Metalized segments
d
e
Contact
Polarizer
Glass back plate
Rear metalized back plate
Liquid crystal (nematic fluid)
Back plate
Segment e
Segment d

Figure C 13.3-4

ACTIVITY SHEET

C 13.4

1. The LED is a light _______________ device.
2. The LED has a _________________ efficiency.
3. To operate properly the LED must be ______________ biased.
4. The LCD is a light-emitting device.

   A. True
   B. False
5. Of the LED and LCD, the ______________ uses less power.
6. The LED converts electrical energy to __________ energy.
7. To produce a green LED, __________ phosphide must be used.
8. To limit the current in LED, a ___________ is used.
9. Two types of character displays are the dot matrix, and the ______________ type.
10. The dome on the LED also serves as a ________________.

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ACTIVITY SHEET KEY C 13.4

1. emitting
2. high
3. forward
4. B
5. LCD
6. light
7. gallium
8. resistor
9. seven
10. lens

PROGRAM: ELECTRONICS

TASK: OPTOELECTRONIC DEVICES

TASK # C 13.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE _______________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT _______________

PERFORMANCE OBJECTIVE:

From a schematic diagram analyze, construct, and troubleshoot optoelectronic devices.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation contact your instructor. You must complete your performance within 30 minutes and must score at least 80 out of 100 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 80 out of 100 points or 80%, and all items items marked with an asterisk (*) must be satisfactorily completed.

OPTOELECTRONIC DEVICES

PERFORMANCE/PRODUCT CHECKLIST

C 13.5

CRITICAL ITEMS	ITEMS TO BE OBSERVED OR CHECKED	RATING YES/NO
1.	Does circuit function correctly?	Y N
*2.	Was circuit wired according to schematic?	Y N
3.	Are connections correct?	Y N
4.	Was necessary data recorded?	Y N
*5.	Was correct equipment used?	Y N
*6.	Was equipment used properly?	Y N
*7.	Were safety precautions followed?	Y N
8.	Was equipment returned to proper storage?	Y N

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

SCORE _____

OPTOELECTRONIC DEVICES

EXAM C 13.6

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on optoelectronic devices. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer 16 out of 20 items correctly, 80%.

EXAM C 13.6

1. The light spectrum lies between 30 GHz and ____________.

   A. 300,000 GHz
   B. 300,000 MHz
   C. 300 Hz
   D. 300,000,000 GHz

2. The photovoltaic cell can be referred to as _____________.

   A. photo cell
   B. solar cell
   C. LED
   D. LCD

3. The photo cell is basically a light sensitive resistor.

   A. true
   B. false

4. The LED constructed of gallium-phosphide will emit light in the ____________ region.

   A. ultraviolet
   B. infrared
   C. visible
   D. blue

5. Light should be considered to be electromagnetic radiation invisible to the human eye.

   A. true
   B. false

6. The photodiode has a higher current output than the phototransistor.

   A. true
   B. false

7. To produce a higher voltage than one cell produces, several solar cells should be connected in _______________.

   A. series
   B. parallel

8. When light strikes a photo cell, the resistance of the cell will ______________.

   A. double
   B. stay the same
   C. lower

9. All light frequencies are visible to the human eye.

   A. true
   B. false

10. All protons that are emitted by the LED are visible.

   A. true
   B. false

11. The LED constructed of gallium-arsenide emits light in the ______________ region.

   A. ultraviolet
   B. infrared
   C. visible
   D. blue

12. The LED is a light- ____________ device.

   A. emitting
   B. sensitive
   C. voltage

13. To operate properly the LED must be ______________ biased.

   A. forward
   B. reversed

14. Incandescent lamps have a longer life expectancy than LED's.

   A. true
   B. false

15. LED's constructed of gallium-arsenide phosphide will emit ____________ color.

   A. yellow
   B. blue
   C. green
   D. red

16. The only purpose of the dome on the LED is to protect the diode.

    A. true
    B. false

17. Two types of character displays are the dot matrix and _______________ segment.

    A. eight
    B. ten
    C. nine
    D. seven

18. The optical coupler is used to provide a high degree of electrical ________________.

    A. voltage
    B. current
    C. accuracy
    D. isolation

19. The dome cover on the LED also acts as a lens.

    A. true
    B. false

20. The field-effect LCD produces ____________.

    A. silver letters on black background
    B. black letters on silver background
    C. green letters
    D. red letters

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EXAM KEY C 13.6

1. D
2. B
3. A
4. C
5. B
6. B
7. A
8. C
9. B
10. B
11. B
12. A
13. A
14. B
15. D
16. B
17. D
18. D
19. A
20. B

ELECTRONICS

ANALYZING ANALOG CIRCUITS

D 1: SINGLE-STAGE TRANSISTOR AMPLIFIERS

TASK: Using a schematic, analyze, construct and troubleshoot single-stage transistor amplifiers.

PURPOSE: Approximately one-half of the field of electronics is analog. To succeed in the field of electronics, it is important to understand the basic applications of simple electronic amplifiers. This learning guide will explain the terms and processes necessary to assist in the understanding of these circuits.

OBJECTIVE: Given a written examination you will analyze and troubleshoot single-stage transistor amplifiers.

ESTIMATED CLASS TIME: 15 HOURS

SINGLE-STAGE TRANSISTOR AMPLIFIERS

LEARNING STEPS

D 1

READ:	Information Sheet D 1.1, "Common Emitter Amplifiers."
COMPLETE:	Activity Sheet D 1.2, "Transistor Biasing."
READ:	Information Sheet D 1.3, "Single-Stage Amplifiers."
READ:	Information on single-stage transistor amplifiers in one or more of the references.
COMPLETE:	Activity Sheet D 1.4, "Single-Stage Amplifiers."
READ:	Information Sheet D 1.5, "Troubleshooting."
COMPLETE:	Activity Sheet D 1.6, "Troubleshooting."
REVIEW:	Information Sheets D 1.1, D 1.3 and D 1.5, and Activity Sheets D 1.2, D 1.4 and D 1.6.
COMPLETE:	Laboratory performance on single-stage transistor amplifiers. Contact your instructor.
READ:	Information Sheet 1.7, "H-parameters and Biasing."
COMPLETE:	Activity Sheet D 1.8, "Biasing."
REVIEW:	Information Sheet D 1.7 and Activity Sheet 1.8.
COMPLETE:	Laboratory performance on H-parameters. Contact your instructor.
COMPLETE:	Performance Checklist D 1.9.
COMPLETE:	Written Exam D 1.10 for mastery of this task.

SINGLE-STAGE TRANSISTOR AMPLIFIERS

RESOURCES

D 1

1. ELECTRONIC PRINCIPLES, 3rd Edition, by Malvino (McGraw-Hill, 1984).
2. ELECTRONICS IN INDUSTRY, 5th Edition, by Chute & Chute (McGraw-Hill, 1979).
3. ESSENTIALS OF SOLID STATE ELECTRONICS, by Faber (Wiley, 1985).
4. SEMICONDUCTOR TECHNOLOGY, by Weedon (Energy Concepts, Inc., 1985).
5. SOLID-STATE ELECTRONICS, 2nd Edition, by Rutkowski (Bobbs-Merrill, 1983).
6. Any appropriate electronics textbook

REQUIRED EQUIPMENT

0 - 25 VDC @ 1A Power Supply
0 - 40 VAC @ 1A Isolated Power Supply
0 - 1IMHZ Function Generator
10 MHZ Dual Trace Oscilloscope
Digital Multimeter

INFORMATION SHEET

D 1.1

FOR TRANSISTORS WITH A BETA BETWEEN 100-400

COMMON EMITTER AMPLIFIERS

Transistor operation depends upon supplying proper voltages to the emitter, base and collector. This is accomplished through the use of simple resistor networks. The simplest method (and least expensive) consists of connecting the base to the collector voltage supply (V_{CC}) through a resistor.

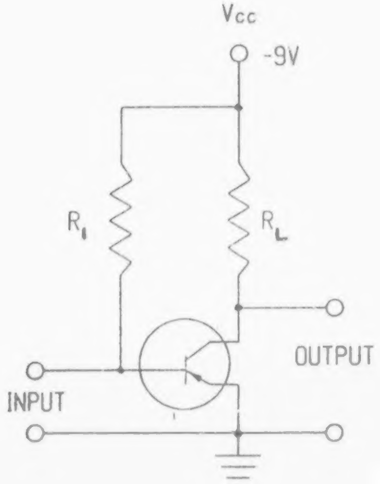


Figure D 1.1-1

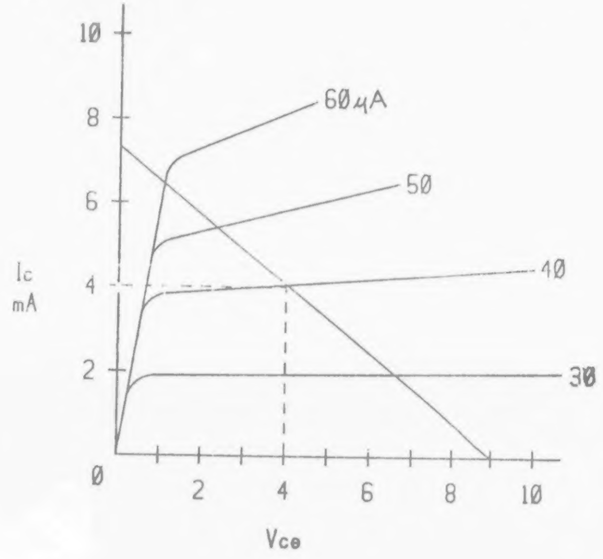


Figure D 1.1-2

From the load line at the right, we have already picked a Q point indicating a quiescent base current of 40 a. This is the exact amount of current that will flow through the bias resistor R_1. Therefore, Ohm's law tells us that R_1 should be a 222,000 ohm resistor.

$$R = E/I = 9/.000040 = 222,000 \text{ ohms}$$

The nearest standard resistance value available is 200,000 ohms and this would be our choice.

Because of the problems involved in temperature stabilization, this current circuit is not as satisfactory as the following circuits.

The second method of providing base bias is similar to the first. However, a degree of temperature stabilization is built in due to degenerative feedback.

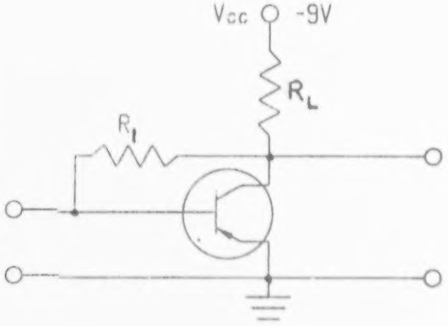


Figure D 1.1-3

In this case, R_1 is connected to the collector instead of V_{CC}. With an increase in collector current, the transistor collector voltage will drop. This drop in collector voltage is transmitted to the base through R_1, resulting in less forward bias. In this situation the transistor is compensating or attempting to shut itself down due to collector current. It should be noted that this is a desirable feature; since current flow through a transistor produces heat and it is this heat for which we are trying to compensate.

R_1 is calculated by using the operating collector voltage rather than V_{CC}. According to the loadline, $V_c = 4$ volts.

$$R_1 = E/I = 4/.000040 = 100,000 \text{ ohms}$$

Additional temperature compensation can be achieved by adding an emitter swamping resistor, R_E.

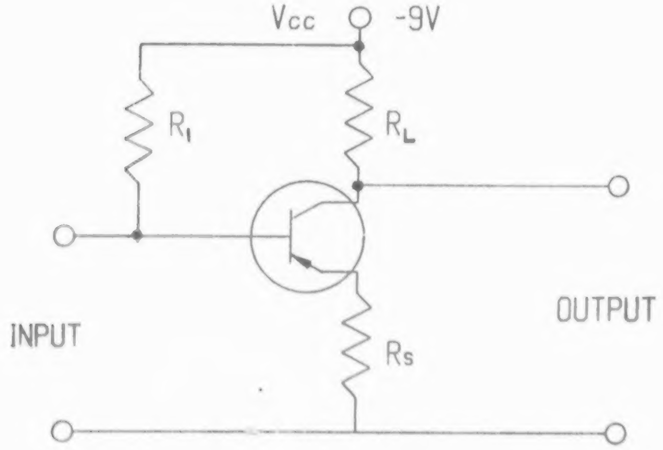


Figure D 1.1-4

This is a very effective method of temperature compensation. However, several side effects are observed.

1. The emitter resistor provides degeneration which results in reduced gain. Since degeneration provides an output with less distortion (higher fidelity) this effect may or may not be desirable.

2. The emitter resistor, due to voltage drop, drops voltage that may be needed for the collector.

3. The addition of an emitter swamping resistor increases the amplifier input impedance considerably. $Z_{in} = r_{in} + BxR_E$.

It should be remembered that as R_E is increased, temperature stabilization is increased, but as the resistance of R_E approaches the resistance of R_L circuit gain is reduced to unity (no gain).

A rule of thumb for determining the value of R_s is that R_s's voltage drop should be approximately 1/10 to 1/12 of V_{CC}. Now, R_s can be calculated by first finding the emitter current I_e from the load line and dividing this amount into the selected voltage drop. (1/12 rule of thumb).

$$R_E = E/I = .75/.004 = 188 \text{ ohms}$$

The nearest standard resistance value is 180 ohms. This would be selected.

The third and best biasing arrangement involves the use of a voltage divider which maintains the base at a constant DC voltage.

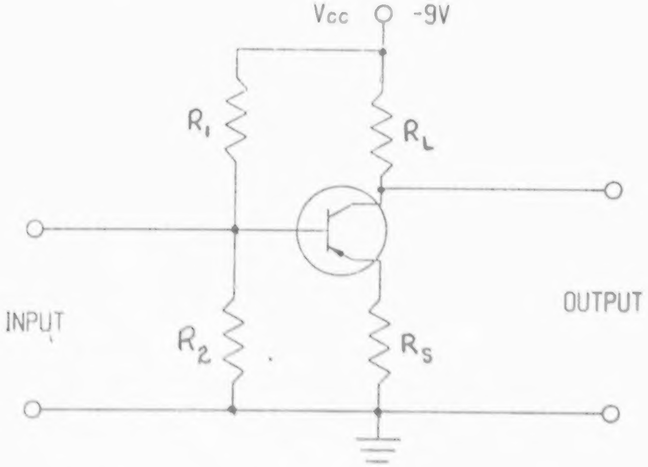


Figure D 1.1-5

This voltage divider consists of R1 and R2. The selection of R1 and R2 involves several considerations, each of which results in a compromise. Lower values of resistance will provide the best temperature stabilization. However, low values of resistance in the voltage divider will reduce the total circuit efficiency, since more current will be drawn from the power source. You will find also that low voltage divider resistance will reduce the circuit input impedance and will shunt part of the input signal to ground.

Here's how to calculate for R1 and R2.

1. Pick a voltage divider current which will flow through both R1 and R2 that is approximately 10 (ten) times the base current. (For example, 40ua = .5ma)

2. Determine what voltage is needed at the base. At this point we must determine whether the transistor is a germanium or silicon unit. A germanium transistor requires a forward bias of about .3 (three-tenths volt) volt. A silicon transistor requires a forward bias of about .7 (seven-tenths) volt. NOTE: This forward bias voltage is in reference to the emitter voltage.

   For a silicon transistor with the emitter operating at -.75 volt (with reference to ground) we will need a base voltage of -1.45 volts. Remember that for a PNP transistor the base must be more negative than the emitter.

As we have just determined, resistor R_2 should have a voltage drop of 1.45 volt.

3. Total voltage divider resistance for a current of .5ma should be 18K.

   $$R = E/I = 0.0005 = 18{,}000 \text{ ohms}$$

4. R_2 is now found by Ohm's Law.

   $$R_2 = E/I = 1.45/.0005 = 2900 \text{ ohms}$$

   The nearest standard value of resistance is 2700 ohms; this selection would be OK.

5. R_1 = 18,000 - 2700 = 15,300 ohms. Again, the nearest standard value of resistance would be 15K.

Except for emitter bypassing (if required) the amplifier design has been completed.

COMMON BASE AMPLIFIERS

The common base amplifier, because of its impedance characteristics and lower power gain is less used than the common emitter configuration. The following characteristics are of interest:

1. Very low input impedance
2. Very high output impedance
3. Low power gain
4. High voltage gain

A low input impedance is realized because the base-emitter junction is biased in the forward or low resistance direction. Also the signal input is injected into the emitter which is more heavily doped than the base or collector. This extra heavy doping results in many additional majority carriers (less resistance).

As was determined in the section on static collector characteristics, the very nearly flat characteristic curves for the common base configuration indicate a very high collector resistance.

Gain for the common base amplifier is the ratio of collector current to emitter current. This ratio is referred to as Alpha, usually abbreviated h_{FB}, or α .

A major use for the common base amplifier includes radio frequency voltage amplifiers used as the input stage in many radio receivers. Besides providing a high voltage gain, it also transforms impedance. There is no phase shift from input to output in this circuit, see Figure D 1.1-6.

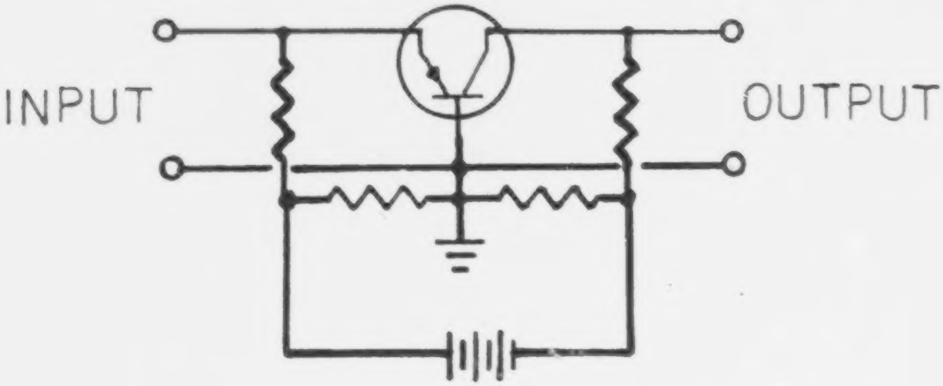


Figure D 1.1-6

COMMON COLLECTOR AMPLIFIER

Referring to Figure D 1.1-6, it should be noted that a negative going input voltage would increase forward bias, thus increasing collector and emitter current. The direction of current flow is such that this increase will cause the emitter to become more negative due to the increased drop across R_E.

The common collector amplifier is so named because the collector is held at signal ground through the battery. As will be noted in Figure D 1.1-7, the collector is common to both input and output. This configuration requires taking the output from the emitter.

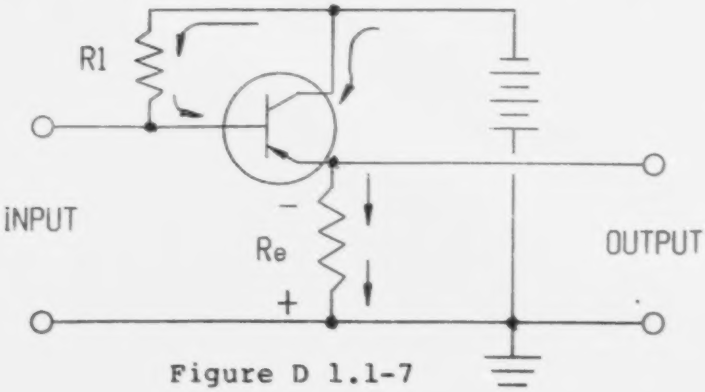


Figure D 1.1-7

Common collector amplifiers are most useful for impedance matching. A very high input impedance and a very low output impedance will be found to be inherently characteristic. Current gain is high (Beta +1); however, voltage gain is less than 1 or unity.

$$I_{Gain} = \frac{I_{Emitter}}{I_{Base}}$$

Voltage loss is due to the forward resistance of the base-emitter junction and a function of Ohm's Law. The difference between input and output voltage will be found to exist across this junction. Even though a voltage loss occurs, a very respectable power gain is usually obtained.

Because the input impedance would be reduced somewhat by a voltage divider biasing arrangement, the base to emitter resistor is often left out of the circuit. The value for R_1 can be found by dividing V_{CC} by I_B and the base current is determined by the collector characteristics.

Input impedance is regulated by Beta and the resistance of R_E and found by:

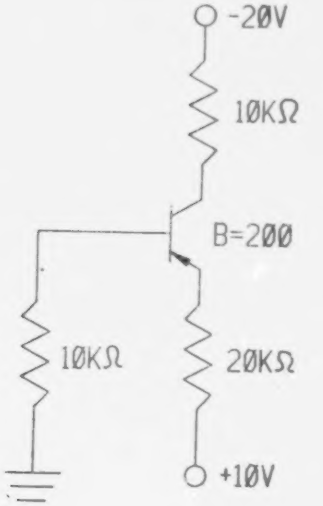
$$Z_{in} = (B + 1)\ (R_E)$$

ACTIVITY SHEET

D 1.2

TRANSISTOR BIASING

Figure D 1.2-1


-20V
10KΩ
B=200
10KΩ
20KΩ
+10V

1. I_c(sat) equals _____ milliamperes.

   A. 0.5
   B. 1.0
   C. 1.5
   D. 2.0
   E. none of the above

2. I_c equals _____ milliamperes.

   A. 0.5
   B. 1.0
   C. 1.5
   D. 2.0
   E. none of the above

3. V_{ce} equals _____ volts.

   A. 0.7
   B. 10
   C. 15
   D. 30
   E. none of the above

4. V_{ce} (cutoff) equals _____ volts.

   A. 0.7
   B. 10
   C. -10
   D. -20
   E. none of the above

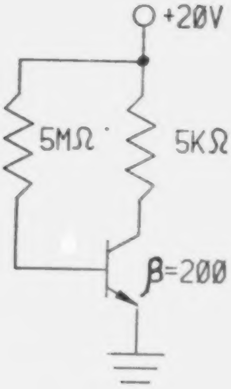


Figure D 1.2-2

5. I_b equals _____ microamperes.

   A. 1.93
   B. 2.47
   C. 3.86
   D. 7.72
   E. none of the above

6. I_c equals _____ milliamperes.

   A. .193
   B. .247
   C. 3.86
   D. .772
   E. none of the above

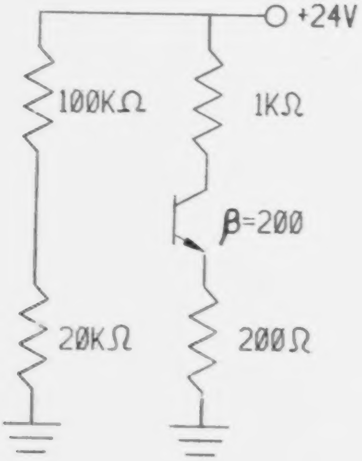
7. I_C(sat) equals _____ milliamperes.

   A. 0
   B. 2
   C. 4
   D. 6
   E. none of the above

8. V_{ce} equals _____ volts.

   A. 3.86
   B. 7.72
   C. 12.28
   D. 16.14
   E. none of the above

Figure D 1.2-3



9. I_C equals _____ milliamperes.

   A. 8.25
   B. 16.5
   C. 24.0
   D. 33.0
   E. none of the above

10. V_{ce} equals _____ volts.

   A. 4.2
   B. 9.7
   C. 12.0
   D. 16.5
   E. none of the above

11. I_b equals _____ microamperes.

    A. 10
    B. 20
    C. 40
    D. 80
    E. none of the above

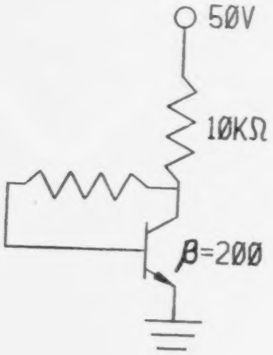
12. I_c(sat) equals _____ milliamperes.

    A. 10
    B. 20
    C. 40
    D. 80
    E. none of the above

13. V_b equals _____ volts.

    A. 0.7
    B. 3.7
    C. 4.0
    D. 4.7
    E. none of the above

Figure D 1.2-4



14. I_c equals _____ milliamperes.

    A. 1.0
    B. 1.5
    C. 2.5
    D. 5.0
    E. none of the above

ACTIVITY SHEET D 1.2 CONT'D.

15. V_{ce} equals _____ volts.

A. 10
B. 20
C. 25
D. 49.3
E. none of the above

16. R_b equals _____ megaohms.

A. 1
B. 2
C. 4
D. 20
E. none of the above

17. I_b equals _____ microamperes.

A. 6.0
B. 12.1
C. 24.65
D. 49.3
E. none of the above

ACTIVITY SHEET D 1.2

ANSWER SHEET

(D) 1. $I_{C(sat)} = \dfrac{-V_{CC}}{R_C} = 2 \text{ mA (D)}$

(A) 2. $I_E = I_C = \dfrac{V_{EE} - V_{BE}}{R_E + R_B/\beta} = \dfrac{10 - .7}{20K + \dfrac{10K}{200}} = .464 \text{ mA} \approx .5 \text{ mA (A)}$

(E) 3. $V_C = V_{CC} - I_C R_C = -20 - (.5 \text{ mA})(10K\Omega) = -15V$

$V_C = -15V$

$V_E = I_E R_E \cong I_C R_E = (.5 \text{ mA})(20K\Omega) = 10V$

$V_{CE} = V_C - V_E = -15-10 = -25 = \text{(E)}$

(D) 4. $V_{CE\ (cutoff)} = V_{CC} = -20V = \text{(D)}$

(C) 5. $I_{C(SAT)} = \dfrac{V_{CC}}{R_C} = I_E = 4 \text{ mA} \qquad \beta = \dfrac{I_C}{I_B}$

$I_B = \dfrac{I_C}{\beta} = 3.9\ \mu\text{A (C)}$

6. D
7. C

(D) 8. $V_{CE} = V_{CC} - I_C R_C$
$= 20 - (.772)(5K)$
$= 16.14 \text{ V}$

$V_{BB} = \dfrac{20K}{100K + 20K}\, .24 = 4V$

$I_C = I_E = \dfrac{V_{BB} - V_{BE}}{R_E} = \dfrac{V_E}{R_E} = \dfrac{3.3}{200} = 16.5 \text{ mA}$

$V_C = V_{CC} - I_C R_C = 7.5 \text{ V} \qquad \beta = \dfrac{I_C}{I_B}$

$V_{CE} = V_C - V_E = 4.2 \text{ V} \qquad I_B = \dfrac{I_C}{\beta} = 82.5\ \mu\text{A}$

ANSWER SHEET D 1.2 (CONT'D)

$$I_{C(SAT)} = \frac{V_{CC}}{R_C+R_E}$$

$$= \frac{24}{1.2K}$$

$$= 20 \text{ mA}$$

9. B
10. A
11. D
12. B
13. C
14. D
15. D
16. B
17. C

INFORMATION SHEET

D 1.3

SINGLE-STAGE AMPLIFIER

The most common type of single-stage amplifier is the common emitter transistor configuration. If you are not familiar with this type of transistor arrangement, do not continue until you obtain the necessary information. The purpose of a transistor in a circuit is to amplify an electrical signal. the ability of a circuit to amplify is called the gain of the circuit. The ability of a transistor to amplify is called the beta of the transistor. There exist two betas for all bipolar transistors. The DC characteristics are represented as h_{FE}, and the AC characteristics are represented as h_{fe}. These two betas are very similar. For discussion in this unit we will consider them to be the same.

The beta of a transistor depends upon many different factors: the transistor construction, the rate of current flow through the transistor, the junction temperature of the transistor, and the circuit in which the transistor is located.

Transistors having the same part number will exhibit differences in beta. For example, a 2N3906 is a silicon PNP transistor. According to the manufacturer's specifications, the transistor is considered good if it has a beta between 100 and 400. Thus you could have two different '06's and one have a beta of 200 and the other a beta of over 400 and both would be good parts. This range of betas for a single transistor increases the difficulty of designing and repairing transistor amplifiers. For any transistor to work properly it must be biased.

There are numerous ways to bias a transistor. In this guide you will study the different ways used to bias a common-emitter transistor amplifier. The purpose of bias is to establish and maintain the transistor voltages and currents at the design values. The set value for each transistor is called the quiescent or Q-point. The Q-point represents the values for I_B, I_C, and V_{CE} with no signal applied.

Available from the maker of the transistor is a data sheet which contains a characteristic curve family for the transistor. Figure D 1.3-1 shows a typical family of curves for a bipolar transistor in the common-emitter configuration. The curves represent the relationship between the values stated earlier. In special cases it is necessary to produce a set of curves. This can be done manually or with the use of a special piece of test equipment called a curve tracer.

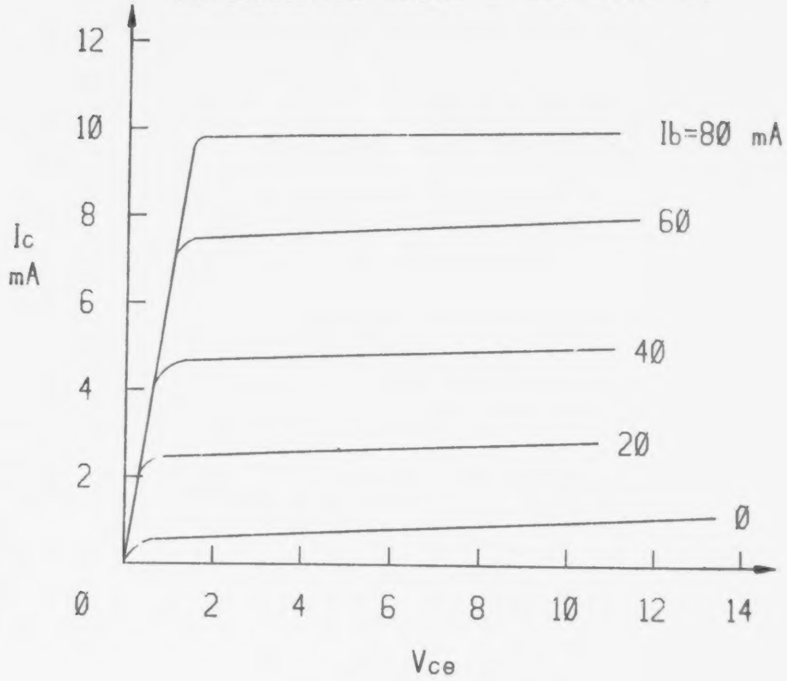


Figure D 1.3-1

Figure D 1.3-2 shows another set of curves. On the curves is a straight line called a load line. The load line is used in the design and repair of the amplifier. There are three important points on the load line; saturation, Q, and cutoff.

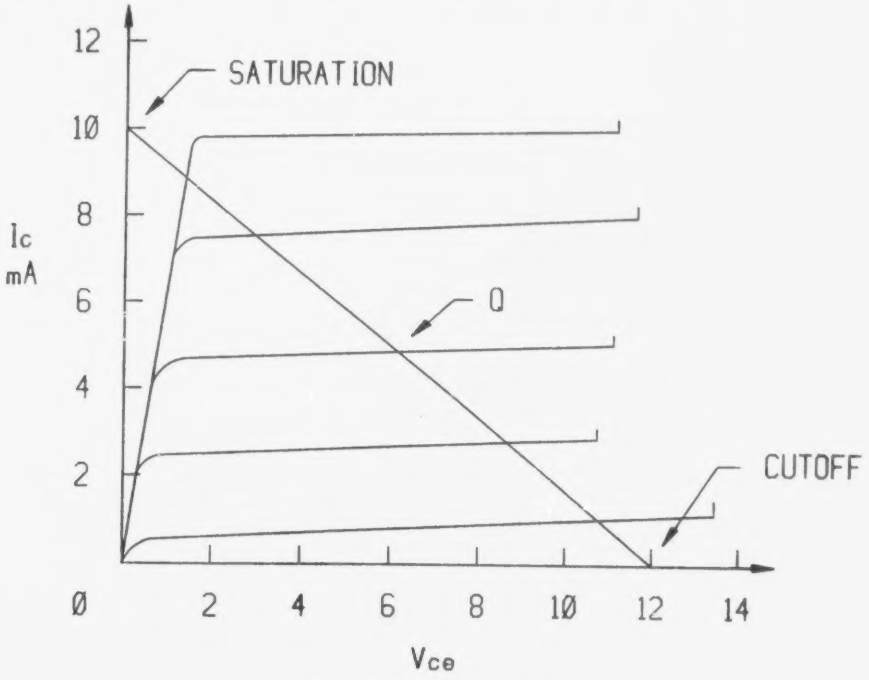


Figure D 1.3-2

There are four basic methods used to establish and maintain the Q-point for a transistor amplifier. The first method is called simple base bias. This method is cheap in that it requires only a single base resistor, but it is very unstable and is sensitive to changes in betas. This arrangement is shown in the Figure D 1.3-3.

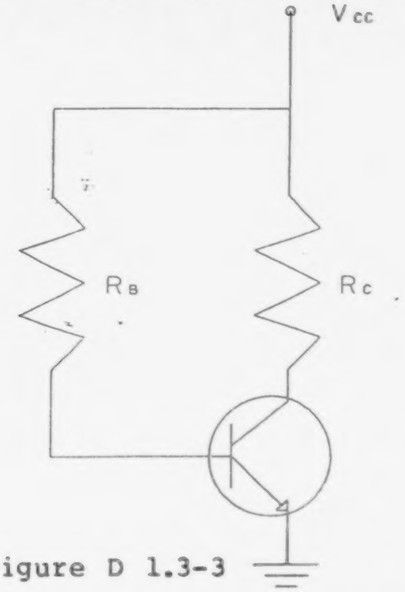


Figure D 1.3-3

The second method shown in Figure D 1.3-4 is a modification of the above arrangement. This is base bias with collector feedback. This provides some increased stability in the bias without additional expense. As we will discuss later, this form of feedback will reduce the overall gain of the transistor amplifier.

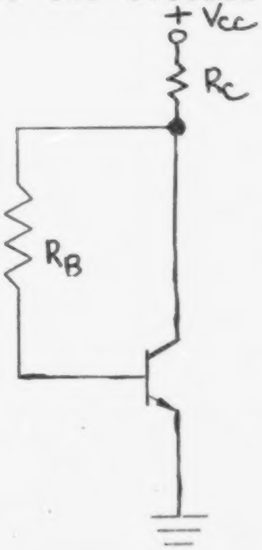


Figure D 1.3-4

The third biasing method is called emitter bias. In this circuit as shown belowin Figure D 1.3-5, a resistor is placed in series with the emitter of the amplifier. This increases the stability of the amplifier greatly, but it does require the additional expense and difficulty of a second power supply.

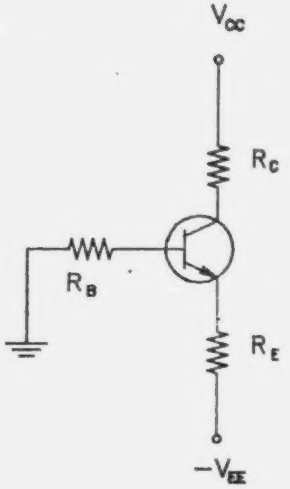


Figure D 1.3-5

The last biasing method shown in Figure D 1.3-6 below is known as voltage divider base bias with emitter feedback. This circuit provides the stability of the previous circuit, without the additional expense of a second power supply. This type of bias is widely used. Its most serious drawback is that the voltage divider does consume a significant amount of energy. This is very important in battery powered devices.

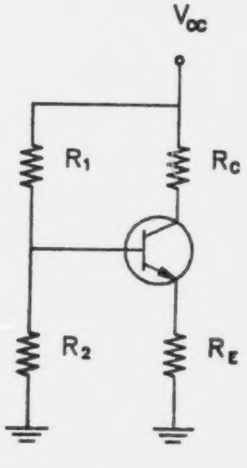


Figure D 1.3-6

The following table presents the different types of biasing arrangements and their characteristics.

	ADVANTAGE	DISADVANTAGE	APPLICATION
BASE BIAS	Simple to use - inexpensive	Sensitive to beta changes	Digital and switching circuits
VOLTAGE-DIVIDER EMITTER BIAS	Stable Q point	Uses more resistors	General purpose amplifiers
BASE-BIAS COLLECTOR FEEDBACK	Simple to use	Moderate sensitivity to B	Small signal amplifiers
DUAL-SUPPLY EMITTER BIAS	Stable Q point	Uses split power supply	General purpose amplifiers

We have just reviewed the different ways to bias a transistor. Let's cover in detail the voltage divider biasing of a transistor with and without emitter feedback. Recall from your earlier studies of transistors that for a bipolar transistor to operate as an amplifier the base-to-emitter diode junction must be forward biased, and the base-to-collector diode junction must be reverse biased.

Bias has to compensate for changes in the temperature of the transistor. This temperature change may result in changes in the surrounding air, ambient temperature. Think about an automobile tape player sitting in below zero temperature. When you get in the car, you expect the device to work. The same expectation is there on a hot 100+ degree summer day. This change in temperature affects the beta and thus the operation of the amplifier.

Through proper design it is possible to reduce the effects of the changing beta. To start with, design the amplifier so that the desired gain of the amplifier is lower than the lowest beta specified for the transistor. This is accomplished by using feedback. This is actually negative feedback. Negative feedback opposes any change in the amplifier status. This increases the stability of the amplifier, and reduces the gain also.

Figure D 1.3-7 shows a properly biased transistor amplifier. The voltage divider consists of R_1 and R_2. The feedback is provided by R_E. When R_E is not in parallel with C_1, the small signal gain of the amplifier is

$$A_v = r_L / R_E$$

This results in a very stable amplifier, but it has a very low gain. To overcome this problem, the emitter is restored to AC ground by the emitter bypass resistor C_1. The gain now becomes

$$A_v = r_L / r_e$$

This maintains the DC stability of the transistor while restoring the AC gain.

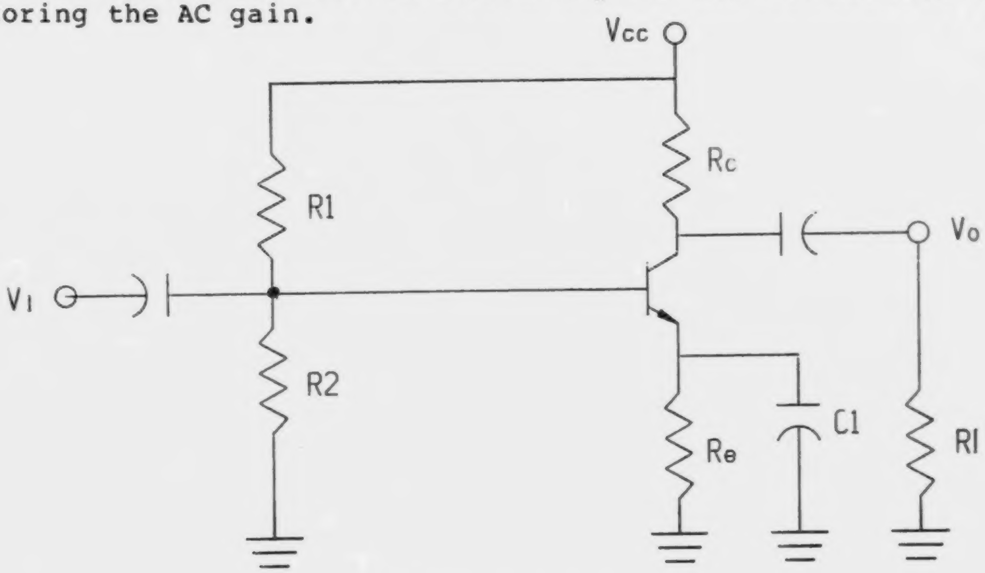


Figure D 1.3-7

An additional concern that biasing addresses is the input and output impedances of an amplifier. The input impedance is the path that the input signal sees to ground. In the case of the voltage divider bias, the input impedance of the circuit is

$$Z_{1(stage)} = R_1 || R_2 || Z_{in(base)}$$

where $Z_{in(base)}$ is either beta times r_e when the emitter is at AC ground, or beta times R_E when the emitter has an unbypassed emitter resistor.

The output impedance of the amplifier is

$$Z_o = RC || rL$$

Another consideration in amplifier design is frequency response. Frequency response of an amplifier is the difference between the lowest and highest frequencies that the amplifier can amplify. This is bandwidth of the amplifier.

The upper and lower cutoff points are determined by the transistor and the external components used in the amplifier respectively. The effects of the coupling capacitors or transformers limit the lower frequency response of the amplifier. The external stray capacitance and internal stray capacitance of the transistor determine the maximum frequency response of the amplifier.

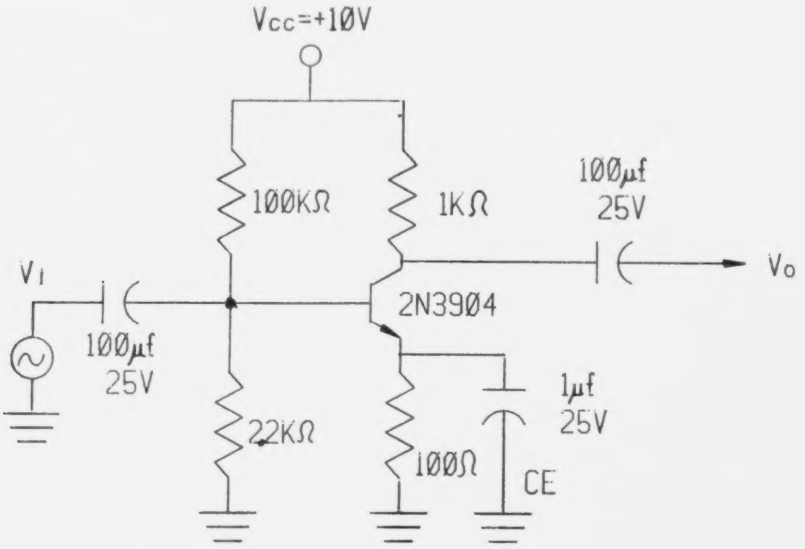
The lower the gain of the amplifier, the greater the bandwidth of the amplifier. This is a result of the extra room available when a transistor is operated below its maximum gain. The additional gain allows the feedback to adjust the gain of the amplifier as the signal changes frequency. An additional effect of negative feedback is that it reduces distortion produced in the amplification process.

ACTIVITY SHEET

D 1.4

SINGLE-STAGE AMPLIFIERS

1. Explain the function of a coupling capacitor.
2. Explain the function of a bypass capacitor.
3. Explain the purpose of bias.
4. Solve the circuit below for the values indicated.


Vcc=+10V
100KΩ
1KΩ
100μf
25V
Vo
Vi
2N3904
100μf
25V
1μf
25V
22KΩ
100Ω
CE

V_{CE} = _____ V_{BE} = _____ V_C = _____ V_B = _____

V_E = _____ A_E W/$_{CE}$ = _____ A_E Wo/$_{CE}$ = _____

Z_i = _____ Z_o = _____

5. Construct the circuit above and measure and record the following.

V_{CE} = _____ V_{BE} = _____ V_C = _____ V_B = _____

V_E = _____

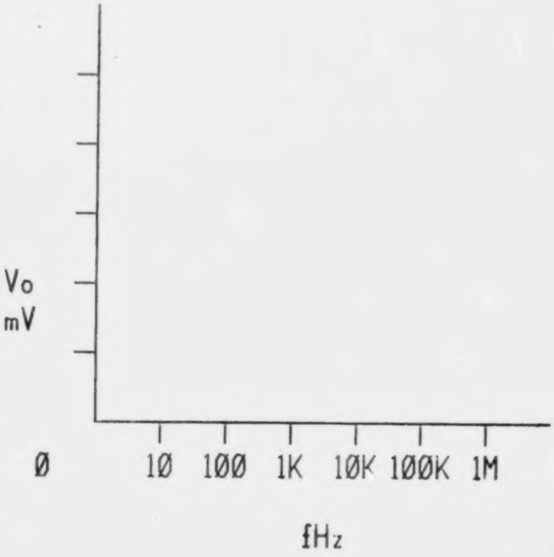
Using the circuit constructed in question #5,

6. Fill in the table below for the given frequencies and input voltages.

Plot the response curve.

Connect and disconnect C_E and measure V_O and A_E.

f In	V_I	V_O		GAIN	
		W/CE	WO/CE	W/CE	WO/CE
10Hz	10mV				
100Hz	10mV				
1KHz					
10KHz					
100KHz					
1MHz					



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ACTIVITY SHEET D 1.4

ANSWER SHEET

1. Isolation, couple AC and block DC.

2. Pass AC variations to ground.

3. Average DC difference in potential measured on the base in respect to the emitter.
Allows the transistor circuit to function as an amplifier and operate in the linear portion of the characteristic curve.

4. $V_{CE} = 4.94V$ $V_C = 6.04V$ $Z_{in} = 1.18K$

$V_B = 1.8V$ $V_{BE} = .7V$ $Z_o = 3.6K$

$V_E = 1.1V$

5. See text.
6. See text.

INFORMATION SHEET

D 1.5

TROUBLESHOOTING

A major concern is the troubleshooting of a transistor amplifier. If you keep certain parameters in mind and use a logical approach, it is not difficult to solve most problems easily and quickly.

There are two conditions which the amplifier is trying to maintain, AC and DC. A few simple measurements and the DC values can be established. To determine if they are correct, remember where the Q-point of the load line is established. It is located near the middle, half way between cutoff and saturation. This means that the voltage measured from the collector to ground should be about half of the cutoff voltage which is the supply voltage. You should measure approximately one-half of the DC supply voltage at the collector.

Next we saw that biasing keeps the base-to-emitter junction forward biased. For a typical silicon, small-signal transistor this will always produce a voltage of approximately .7 VDC. This must be there or the transistor cannot operate properly. If either of these values are off by more than 20% you have a DC problem. If all the DC values are correct, check the AC values.

Remember that the AC gain of the amplifier will be severely reduced if the emitter by-pass capacitor should open. Also there will be no signal if the input-coupling capacitor should open. Should the output capacitor open there will be a signal on the collector of the amplifier, but not at the load. Should we be concerned about shorting capacitors? If the bypass capacitor shorts it will drastically affect the collector voltage by pulling it almost to ground. Should either of the coupling capacitors short, they will usually affect the DC bias voltages during the DC voltage check taken earlier.

ACTIVITY SHEET

D 1.6

TROUBLESHOOTING

1. Troubleshoot one or more typical electronic amplifiers.

2. Report your findings and indicate the method of correcting the problem.

ACTIVITY SHEET D 1.6

ANSWER SHEET

THE ANSWERS WILL BE CIRCUIT/HARDWARE DEPENDENT.

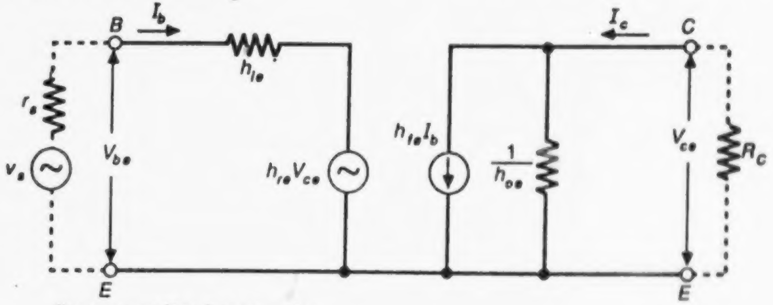
INFORMATION SHEET

D 1.7

H-PARAMETERS AND BIASING

A set of parameters for circuit analysis is the hybrid parameters, or h-parameters. These parameters are used for the AC analysis of transistor circuits. DC current gain factors are also expressed in h-parameters.

Figure D 1.7-1 shows a common emitter h-parameter equivalent circuit. The signal source is indicated by v_s and r_s, and the collector resistor is R_C.



Common emitter *h*-parameter equivalent circuit

Figure D 1.7-1

The input of an h-parameter circuit is an input resistance h_{ie} in series with the voltage h_{re}·XV$_{ce}$. The voltage represented by h_{re} is a feedback voltage that is developed across r_e.

The output of an h-parameter circuit is an output resistance $1/h_{oe}$ which is in parallel with the current generator h_{le}·I_b. I_b is the AC base current. $h_{fe}I_b$ is the result of input current I_b which divides between the device output resistance and the collector resistor R_c. I_c is the current through R_c.

Definition of the Common Emitter *h*-Parameters.

$$h_{ie} = \text{input resistance} = \left.\frac{\Delta V_{BE}}{\Delta I_B}\right|_{V_{CE}} \quad \text{ohms } (\Omega)$$

$$= \frac{\text{variation in (input) base-emitter voltage}}{\text{variation in (input) base current}} \quad (\text{when } V_{CE} \text{ is held constant})$$

$$= \left.\frac{V_{be}}{I_b}\right|_{V_{CE}} \quad (\text{using ac quantities})$$

$$h_{re} = \text{reverse voltage transfer ratio} = \left.\frac{\Delta V_{BE}}{\Delta V_{CE}}\right|_{I_B}$$

$$= \frac{\text{variation in (input) base-emitter voltage}}{\text{variation in (output) collector-to-emitter voltage}} \quad (\text{when } I_B \text{ is held constant})$$

$$= \left.\frac{V_{be}}{V_{ce}}\right|_{I_B}$$

$$h_{fe} = \textbf{forward current transfer ratio} = \left.\frac{\Delta I_C}{\Delta I_B}\right|_{V_{CE}}$$

$$= \frac{\text{variation in (output) collector current}}{\text{variation in (input) base current}} \quad \text{(when } V_{CE} \text{ is held constant)}$$

$$= \left.\frac{I_c}{I_b}\right|_{V_{CE}}$$

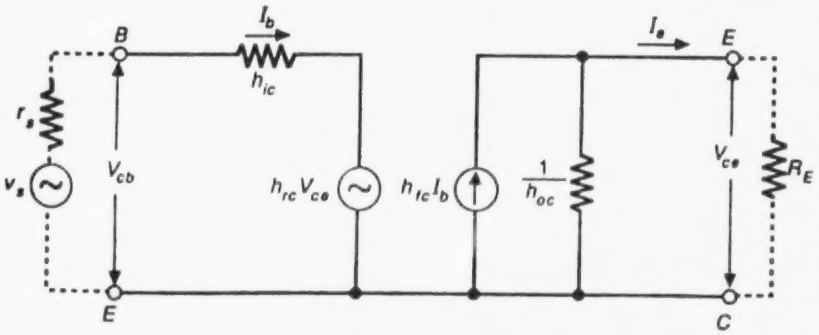
The dc forward current transfer ratio (β_{dc}) is also written as h_{FE}. Note that to indicate that this is a dc parameter, the subscript *FE* is used instead of *fe*.

$$h_{oe} = \textbf{output conductance} = \left.\frac{\Delta I_C}{\Delta V_{CE}}\right|_{I_B} \quad \text{siemens (S)}$$

$$= \frac{\text{variation in (output) collector current}}{\text{variation in (output) collector-to-emitter voltage}} \quad \text{(when } I_B \text{ is held constant)}$$

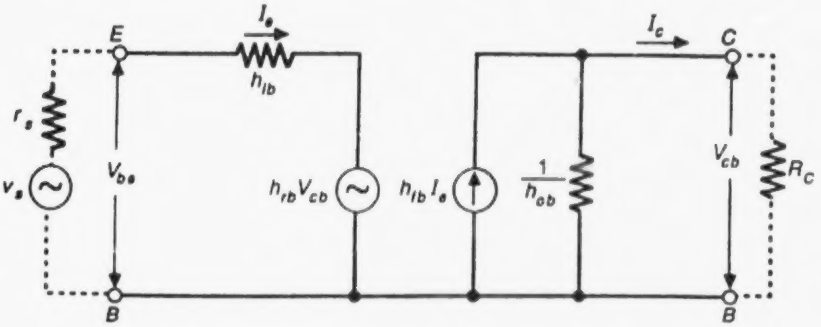
$$= \left.\frac{I_c}{V_{ce}}\right|_{I_B}$$

The h-parameters for common collector and common base configurations are defined similarly to the common emitter h-parameters. Their h-parameter equivalent circuits are shown below in Figures D 1.7-2 and D 1.7-3.



Common collector *h*-parameter equivalent circuit.

Figure D 1.7-2



Common base *h*-parameter equivalent circuit.

Figure D 1.7-3

INFORMATION SHEET D 1.7 CONT'D.

Manufacturers' data sheets usually do not list the values for all parameters. If any are given, they are only stated for the common emitter. Table D 1.7-1 shows the conversion from common emitter parameters to common collector and common base. Also shown is the conversion from h-parameters to r-parameters. You will recognize the r-parameters as those used in the introduction of transistor circuit analysis.

Parameter Conversion from Common Emitter to Common Collector, Common Base and *r*-Parameters

Common Emitter to Common Collector	Common Emitter to Common Base	Common Emitter *h*-parameters to *r*-parameters
$h_{ic} = h_{ie}$	$h_{ib} \approx \dfrac{h_{ie}}{1 + h_{fe}}$	$\alpha \approx \dfrac{h_{fe}}{1 + h_{fe}}$
$h_{rc} = 1 - h_{re}$	$h_{rb} \approx \dfrac{h_{ie}\,h_{oe}}{1 + h_{fe}} - h_{re}$	$r_c = \dfrac{1 + h_{fe}}{h_{oe}}$
$h_{fc} = -(1 + h_{fe})$	$h_{fb} \approx -\dfrac{h_{fe}}{1 + h_{fe}}$	$r_e = \dfrac{h_{re}}{h_{oe}}$
$h_{oc} = h_{oe}$	$h_{ob} \approx \dfrac{h_{oe}}{1 + h_{fe}}$	$r_b = h_{ie} - \dfrac{h_{re}(1 + h_{fe})}{h_{oe}}$

Table D 1.7-1

Now let's investigate some of the previous bias circuits using h-parameters. The first bias circuit uses collector-to-base bias as shown in Figure D 1.7-4. Given the following, let's design an amplifier as shown below. V_{CC} = 15 V, V_{CE} = 5V, I_C = 5mA, and h_{FE} = 100.

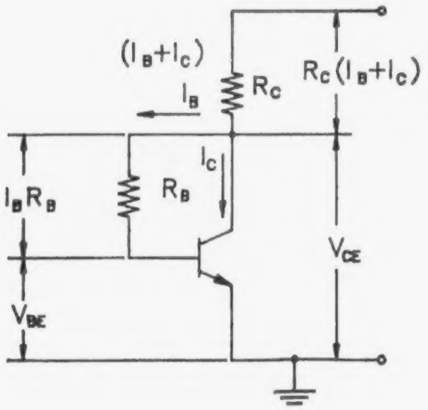


Figure D 1.7-4

DC gain or Beta is equal to h_{FE}; therefore

$$I_B = \frac{I_C}{h_{FE}} = \frac{5\text{mA}}{100} = 50\ \mu\text{A}$$

and

$$R_B = (V_{CE} - V_{BE})/I_B$$

$$= (5\text{V} - 7\text{V})/50\mu\text{A} = 85\text{k ohms.}$$

The closest lower standard value is 82K ohms.

The collector resistor R_C is

$$R_C = (V_{CC} - V_{CE})/(I_B + I_C)$$

$$= (15\text{V} - 5\text{V})/(50\mu\text{A} + 5\text{mA}) = 1.98\text{k ohms.}$$

The closest lower standard value is 1.8k ohms. As previously stated, this form of bias heavily affected by changes in h_{FE}.

Figure D 1.7-5 shows emitter bias using a single supply. This circuit is very stable, and is unaffected by changes in h_{FE} which does not even appear in any of the equations. Operation from a single supply is possible because resistors R_1 and R_2 divide the supply voltage V_{CC} to provide the base bias voltage. Resistor R_E is in series with the emitter terminal of the transistor.

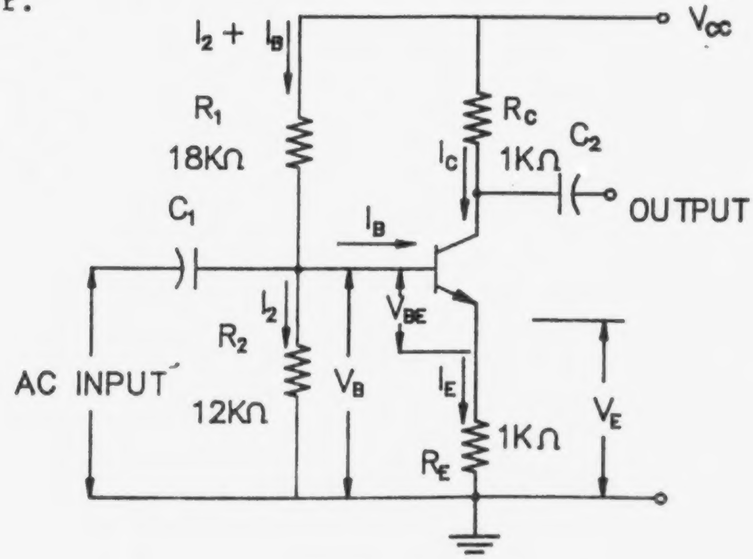


Figure D 1.7-5

INFORMATION SHEET D 1.7 CONT'D.

The voltage drop across R_E is

$$V_E = I_E \times R_E$$

and

$$V_E = I_B \times V_{BE}.$$

Therefore,

$$I_E = (V_B - V_{BE})/R_E$$

when $V_B >> V_{BE}$

$$I_E = V_B/R_E;$$

also,

$$I_2 = I_C/10$$

to maintain bias stability, and keep the input resistance of the amplifier as high as possible.

$V_B = V_{CC} \times (R_2/(R_1 + R_2))$ and $I_E = (V_B = V_{BE})/R_E$.

Allowing that $I_C = I_E$, $V_{CE} = V_{CC} - I_E (R_C + R_E)$.

To investigate more deeply the operation of this circuit, it may be redrawn as shown in Figure D 1.7-6.

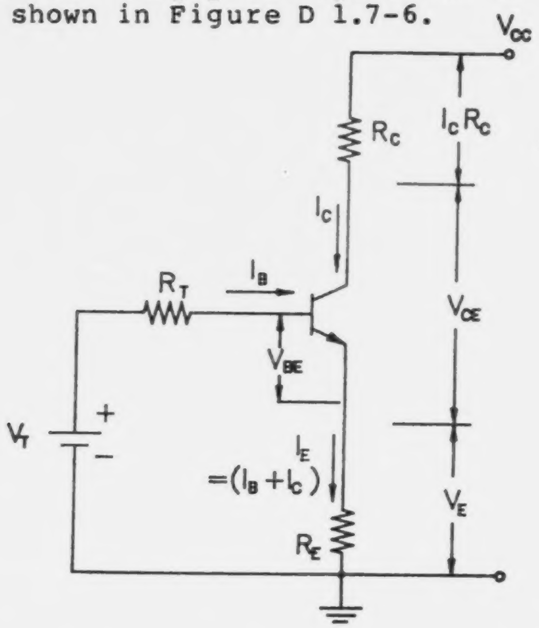


Figure D 1.7-6

The bias resistors R_1 and R_2 have been replaced by their Thevenin equivalent circuit where $V_T = V_{CC} \times R_2/(R_1 + R_2)$ and $R_T = R_1 || R_2$. Applying these equations to the above equation,

$V_{CC} = I_C R_C + R_E (I_B + I_C)$ and $V_T = I_B R_T + V_{BE} + R_E (I_B + I_C)$.

Using the previous figures and equations, design and analyze an emitter bias circuit with $V_{CC} = 15V$, $V_{CE} = 5V$, $I_C = 5mA$, and with an h_{FE} of 50 and then of 150.

INFORMATION SHEET D 1.7 CONT'D.

$$V_T = V_{CC} \times R_2/(R_1 + R_2)$$
$$= 15V \times 11.4k\Omega/(18.6k\Omega + 11.4k\Omega)$$
$$= 5.7V;$$

in that $R_T = R_1 || R_2$

$$R_T = 18.6k\Omega || 11.4k\Omega = 7.07k\Omega .$$

By substituting $I_B = I_c \backslash h_{FE}$ in

$$V_T = I_B R_T + V_{BE} + R_E (I_B + I_C)$$

resulting in

$$V_T = (I_c/h_{FE}) \times R_T + V_{BE} + R_E \times (I_c \backslash h_{FE} + I_c)$$

which simplifies to

$$I_c = \frac{V_T - V_{BE}}{(R_T h_{FE}) + R_E (1/h_{FE} + 1)}.$$

Now with $h_{FE} = 50$

$$I_c = \frac{5.7V - 5.7V}{(7.07k\Omega/50) + 1k\Omega(1/50 + 1)}$$
$$= 4.31 \text{ mA},$$

and with $h_{FE} = 150$ the collector current becomes

$$I_C = \frac{5.75V - 0.7V}{(7.07k\Omega/150) + 1k\Omega(1/150 + 1)}$$
$$= 4.74 \text{ mA}.$$

The voltage collector to emitter, V_{CE} becomes

$$V_{CE} = V_{CC} - I_C R_C - R_E (I_C/h_{FE} + I_C).$$

Again with $h_{FE} = 50$

$$V_{CE} = 15V - (4.31mA \times 1k\Omega) - 1k\Omega (4.31mA/50 + 4.31mA)$$
$$= 6.29V;$$

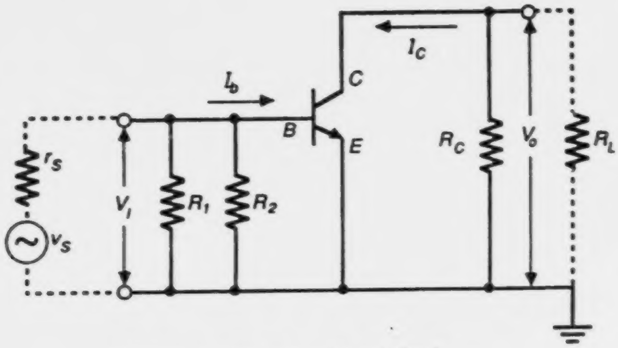
with h_{FE} = 150 V_{CE} becomes

$$V_{CE} = 15V - (4.74mA \times 1k\Omega\ ) - 1k\Omega\ (4.74mA/150 + 4.74mA)$$

$$= 5.49V.$$

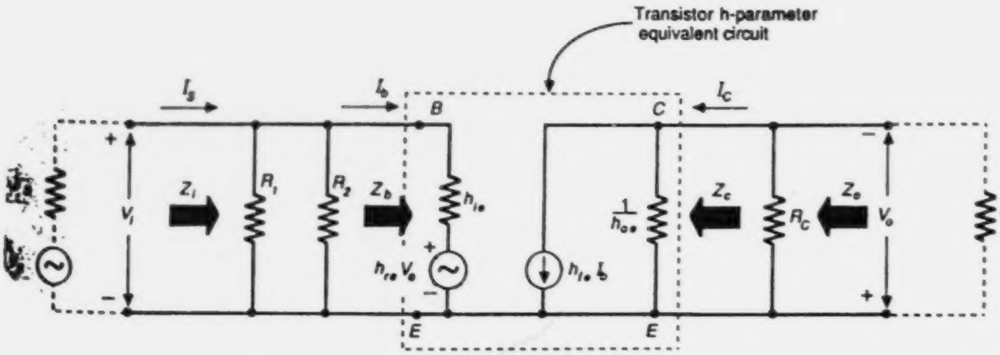
To use the above equations for a circuit where R_E is by-passed, substitute r_e for R_E.

H-parameters are also used in the calculation of the input and output impedances, voltage gain, current gain and power gain of an amplifier. The following section covers the use of these parameters for the common emitter circuit configuration. Study Figures D 1.7-7 and D 1.7-8 which show the AC equivalent circuit for a common emitter amplifier with its emitter feedback resistor by-passed (Figure D 1.7-7), and its h-parameter equivalent circuit (Figure D 1.7-8).


I_C
I_b
C
B
E
r_S
v_S
V_i
R_1
R_2
R_C
V_o
R_L

Common emitter ac equivalent circuit.

Figure D 1.7-7


Transistor h-parameter equivalent circuit
I_s
I_b
B
C
I_c
+
V_i
−
Z_i
R_1
R_2
Z_b
h_{ie}
$h_{re}V_o$
+
−
$h_{fe}I_b$
$\frac{1}{h_{oe}}$
Z_c
R_C
Z_o
−
V_o
+
E
E
R_L

common emitter *h*-parameter circuit

Figure D 1.7-8

In the h-parameter circuit, Figure D 1.7-8, shown h_{ie} is in series with $h_{re}V_o$, the feedback voltage. Because h_{re} is very small, the voltage fed back is much smaller than the input voltage drop across h_{ie}. This results in the input impedance of the amplifier being approximately equal to

$$Z_b = h_{ie}.$$

For this type of circuit a typical range for h_{ie} is 1k to 2K ohms.

Figure D 1.7-9 shows the AC equivalent circuit for a common emitter amplifier without its emitter feedback resistor bypassed, and Figure D 1.7-10 shows its h-parameter equivalent circuit.

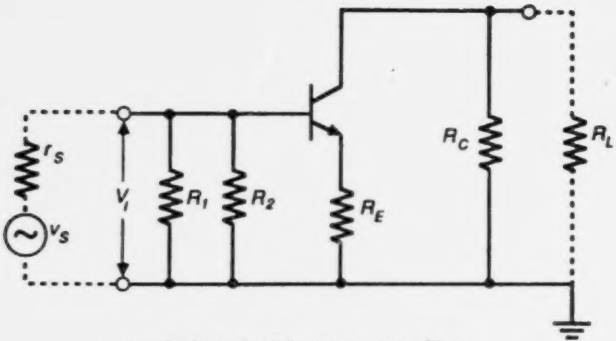

r_s
v_s
V_i
R_1
R_2
R_E
R_C
R_L

Figure D 1.7-9

ac equivalent circuit for common emitter amplifier with an unbypassed emitter resistor R_E

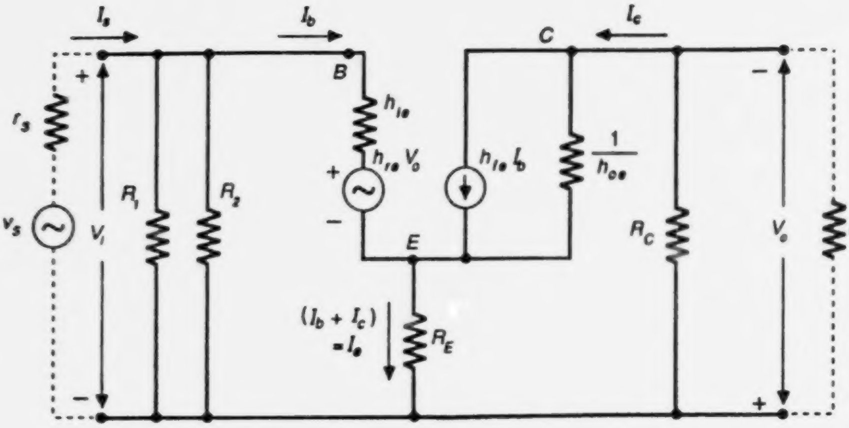

I_s
I_b
I_c
C
B
E
h_{ie}
$h_{re}V_o$
$h_{fe}I_b$
$\frac{1}{h_{oe}}$
r_s
v_s
V_i
R_1
R_2
$(I_b + I_c) = I_e$
R_E
R_C
V_o
R_L
+
−

Figure D 1.7-10

COMMON EMITTER H-PARAMETER CIRCUIT WITH EMITTER RESISTOR UNBYPASSED

Remember that in this application $h_{re}V_o$ is assumed to be zero. The input impedance is slightly more difficult to calculate.

$$\begin{aligned} V_i &= I_b h_{ie} + I_E R_B \\ &= I_b h_{ie} + R_E(I_b + I_C) \\ &= I_b h_{ie} + R_E I_b + R_E h_{fe} I_b \\ &= I_b[h_{ie} + R_E(1 + h_{fe})] \end{aligned}$$

if

$$z_b = V_i/I_b.$$

The input impedance into the amplifier becomes

$$z_i = R_1||R_2||z_b.$$

Because the output voltage of a common emitter amplifier is not reflected back to the input, the transistor output impedance is seen as a large resistance equal to

$$z_C = 1/h_{oe}$$

For the typical transistor used in this type of circuit, z_c is usually 1M ohm or greater.

And because the circuit load is in parallel with the collector resistor, the output impedance for the amplifier is

$$z_O = (1/h_{OE})||R_C.$$

Because R_C is usually much less than z_C the output impedance can be approximated as R_C.

The voltage gain for this type of amplifier with its emitter resistor bypassed is

$$A_V = \frac{-h_{fe}(R_c//R_l)}{h_{ie}}.$$

The negative sign indicates that the output voltage is 180° out of phase with the input voltage.

The voltage gain without the emitter resistor bypassed is

$$\begin{aligned} V_I &= i_b h_{ie} + I_e R_E \\ &= I_b h_{ie} + R_E(I_b + I_c) \\ &= I_b h_{ie} + R_E I_b(1 + h_{fe}) \\ &= I_b[h_{ie} + R_E(1 + h_{fe})] \end{aligned}$$

and $$A_v = \frac{V_o}{V_i} = \frac{I_c(R_C||R_L}{I_b[h_{ie} + R_E(1 + h_{fe})]} = \frac{-h_{fe}(R_C||R_L}{h_{ie} + R_E(1 + h_{fe})}.$$

Because $R_E(1 + h_{fe})$ is usually much greater than h_{ie}

$$A_v = -(R_C||R_L)/R_E.$$

Current gain for the transistor is $h_{fe} = I_c/I_b$, but this is not the current gain for the circuit. Remember the input current goes into the bias resistance R_B which is composed of resistors R_1 and R_2. These resistors are in parallel with the input impedance of the transistor, Z_b. The current gain for the circuit is equal to the output load current divided by the input signal current, I_L/I_8.

$$A_i = \frac{I_L}{I_3} = \frac{h_{fe}R_cR_E}{(R_C + R_L)(R_B + Z_6)}.$$

The power gain for the circuit is simply $A_p = A_v \times A_i$.

The following is a summary for the common emitter circuit without and with R_E and the common collector circuit.

Summary of Typical CE Circuit Performance
Without R_E in the Circuit:

Input impedance	Z_b	h_{ie}
Circuit input impedance	Z_i	$R_B\|\|Z_b = R_1\|\|R_2\|\|Z_b$
Output impedance	Z_c	$1/h_{oe}$
Circuit output impedance	Z_o	$R_C\|\|1/h_{oe}$ R_C
Circuit voltage gain	A_v	$\frac{h_{fe}(R_C\|\|R_L)}{h_{ie}}$
Current gain	h_{fe}	$= \frac{I_C}{I_B}$ CE
Circuit current gain	A_i	$\frac{h_{fe}R_BR_C}{(R_B + Z_n)(R_C + R_L)}$
Circuit power gain	A_p	$= A_v \times A_i$

INFORMATION SHEET D 1.7 CONT'D.

With R_E Included in the Circuit:

Input impedance	Z_b	$h_{ie} + R_E(1 + h_{fe})$
Circuit input impedance	Z_i	$R_B \parallel Z_b$
Voltage gain	A_v	$(R_C \parallel R_L)/R_E$

Summary of Typical CC Circuit Performance

Input impedance	Z_b	$h_{ie} + H_{fe}(R_E \parallel R_L)$
Circuit input impedance	Z_i	$R_1 \parallel R_2 \parallel Z_b$
Output impedance	Z_e	$\frac{h_{ie} + (R_1 \parallel R_2 \parallel r_s)}{h_{fe}}$
Circuit output impedance	Z_o	$E_E \parallel Z_e \quad Z_e$
Voltage gain	A_v	1
Current gain	$h_{fc} = 1 + h_{fe}$	
Circuit current gain	A_i	$\frac{h_{fe}R_BR_E}{(R_B + Z_n)(R_C + R_L)}$
Circuit power gain	A_p	A_i

Using figure D 1.7-11 below and the transistor parameters of h_{ie} = 2.1k ohms, and h_{fe} = 75, calculate the input, output impedance and the voltage gain. Assume that R_L is much larger than R_E.

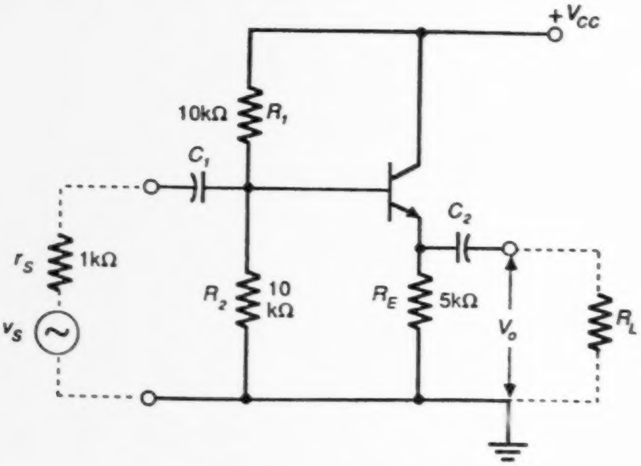


Figure D 1.7-11

Referring back to the table of parameter conversions,

$$h_{ic} = h_{ie} = 2.1\text{k ohms}$$
$$hfc = 1 + h_{fe} = 76.$$

From the previous summary,

$$Z_b = 2.1\text{k}\Omega + (76 \times 5\text{k}\Omega) = 382.1\text{k ohms.}$$

The input impedance is

$$Z_1 = 382\text{k}\Omega \,||\, 10\text{k}\Omega \,||\, 10\text{k}\Omega = 4.94\text{k ohms.}$$
$$Z_e = [2.1\text{k}\Omega + (1\text{k}\Omega \,||\, 10\text{k}\Omega)/76 = 38.6\text{ ohms.}$$

This results in an output impedance of

$$Z_o = 38.6\,\Omega \,||\, 4.94\text{k}\Omega = 38.3\text{ ohms.}$$

Let's investigate the effect of a 5k ohm load connected to the circuit using capacitor C_2 on Z_i and Z_o.

$$Z_b = 2.1\text{k}\Omega + 76(5\text{k}\Omega \,||\, 5\text{k}\Omega)$$
$$= 192\text{k ohms}$$

$$Z_i = 192\text{k}\Omega \,||\, 10\text{k}\Omega \,||\, 10\text{k}\Omega$$
$$= 4.87\text{k ohms.}$$

Z_e does not change and remains equal to 38.6 ohms.

$$Z_o = 38.6\,\Omega \,||\, 4.87\text{k}\Omega = 38.6\text{ ohms.}$$

Notice that going from no load to a load of 5k ohms has no effect on the impedances of the circuit.

ACTIVITY SHEET

D 1.8

BIASING

1. Define h_{ie} for a common emitter.

2. Define h_{re} for a common emitter.

3. Define h_{fe} for a common emitter.

4. Define h_{oe} for a common emitter.

Using Figure D 1.8-1 below, determine R_B, and R_C when V_{CC} = 12V, V_{CE} = 4V, I_C = 10 mA, and h_{FE} = 75.

5. R_B =

6. R_C =

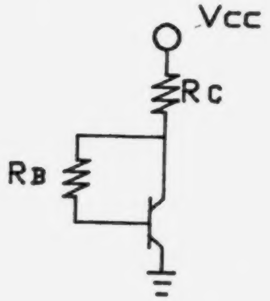


Figure D 1.8-1

Using Figure D 1.8-2, determine Z_b, Z_i, Z_o, and A_v, when V_{CC} = 12V, I_C = 2.4 mA, h_{ie} = 1k, and h_{FE} = 150.

7. Z_b =

8. Z_i =

9. Z_o =

10. A_v =

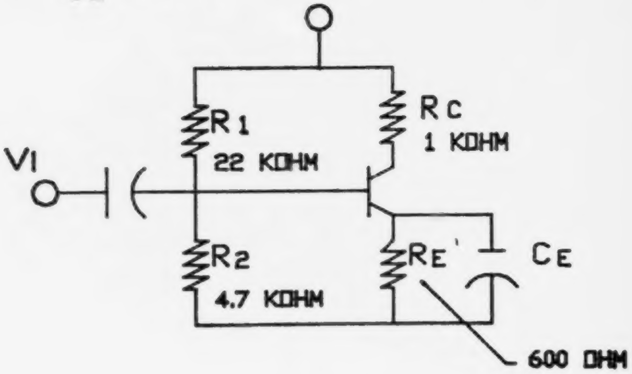

R1
22 KOHM
Rc
1 KOHM
VI
R2
4.7 KOHM
RE
CE
600 OHM

Figure D 1.8-2

ACTIVITY SHEET D 1.8

ANSWER SHEET

1 - 4 See text.

Collector bias NPN circuit.

5. $R_B = = (V_{CC} - V_{BE})/I_B = (4V - .7V)/13\text{ mA} = 154K\ /220K$ or 270K

$$I_B = \frac{I_C}{h_{fe}} = \frac{.01}{-75} = 1.3 \times 10^{-5}A$$

6. $R_C = (V_{CC} - V_{CE})(I_B + I_C = (12V - 4V)/(13\text{ mA} + 10\text{mA}) = 8V/10\text{mA} = 800\ /820$

Voltage divider bias with emitter feedback, NPN with bypass capacitor.

7. $Z_b = 90K\Omega$

8. $Z_i = 90K||22K||4.7K = 3.7K\,\Omega$

9. $Z_o = R_c = 1K\Omega$

10. $$A_v = \frac{-R_C}{r_e} = \frac{-h_{fe} \times R_C}{h_{ie}} = \frac{-150 \times 1K}{11K} = -150$$

PROGRAM: ELECTRONICS

TASK: SINGLE-STAGE TRANSISTOR AMPLIFIERS

TASK # D 1.9

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ___________________ EVALUATION SITE ____________

EVALUATOR'S NAME _________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ____________

TERMINAL PERFORMANCE OBJECTIVE:

USING A SCHEMATIC, ANALYZE, CONSTRUCT AND TROUBLESHOOT SINGLE-STAGE TRANSISTOR AMPLIFIERS.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 7 out of 8 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 7 out of 8 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

SINGLE-STAGE TRANSISTOR AMPLIFIERS

D 1.9

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was 100% of experiment completed?	Y N
2.	Did the experiment function as designed?	Y N
3.	Was the required equipment used?	Y N
*4.	Was the required data recorded?	Y N
5.	Was the equipment used according to specifications?	Y N
*6.	Were all safety precautions followed?	Y N
7.	Was the equipment returned to the proper storage area?	Y N
*8.	Was the experiment summarized properly?	Y N

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

STUDENT'S SCORE ______

SINGLE-STAGE TRANSISTOR AMPLIFIERS

EXAM D 1.10

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Single-Stage Transistor Amplifiers. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer a minimum of 28 out of 35 items correctly, 80%.

SINGLE-STAGE TRANSISTOR AMPLIFIERS

EXAM

D 1.10

Questions 1-14 refer to the circuit shown in Figure D 1.10-1.

1. The circuit is a _____ amplifier.

   A. common base
   B. common emitter
   C. common collector
   D. none of the above

2. The DC-emitter current equals _____ milliamperes.

   A. .20
   B. .43
   C. 1.0
   D. 2.0

3. The emitter-diode AC resistance equals _____ ohms.

   A. 25
   B. 53.5
   C. 71.4
   D. 125.0

4. The DC-collector voltage equals _____ volts.

   A. 2.14
   B. 4.31
   C. 6.67
   D. 8.50

5. The DC-emitter voltage equals _____ volts.

   A. 3.64
   B. 4.00
   C. 5.90
   D. none of the above

6. The DC-output voltage equals _____ volts.

   A. 1.60
   B. 3.33
   C. 5.00
   D. none of the above

EXAM D 1.10 CONT'D.

7. The input impedance looking into the base equals _____ ohms.

A. 12.5K
B. 15.0K
C. 16.5K
D. none of the above

8. The input impedance of the stage is _____ ohms.

A. 7.84
B. 9.24K
C. 21.1K
D. none of the above

9. The voltage gain equals _____.

A. 1.33
B. 6.97
C. 40.3
D. 53.3

10. What is the output voltage if the input voltage is 1 millivolt?

A. 1.33
B. 6.97
C. 40.3
D. 53.3

11. What is the gain of the circuit if capacitor C_e is open?

A. .28
B. .37
C. .44
D. .53

12. What will the DC-output voltage equal if C_2 is open?

A. 9.15
B. 7.38
C. 0.99
D. none of the above

13. The circuit uses _____ bias.

A. collector-feedback
B. emitter
C. voltage-divider
D. self

14. What is the maximum peak-to-peak input voltage permitted to insure small signal operation?

    A. 2.5mv
    B. 6.8mv
    C. 100mv
    D. 120mv

Questions 15-21 refer to the circuit shown in Figure D 1.10-2.

15. This circuit is a _____ amplifier.

    A. common base
    B. common emitter
    C. common collector
    D. none of the above

16. This type of biasing is called _____ bias.

    A. base
    B. emitter
    C. voltage divider
    D. collector feedback

17. The DC-emitter current equals _____ milliamperes.

    A. .25
    B. .33
    C. .50
    D. none of the above

18. The DC-collector voltage equals _____ volts.

    A. 0.7
    B. 9.3
    C. 16.6
    D. 10.3

19. The emitter-diode AC resistance equals _____ ohms.

    A. 7.46
    B. 9.30
    C. 50.0
    D. 133.7

20. The voltage gain equals _____.

A. 35
B. 81
C. 131
D. 627.2

21. The input impedance of the stage equals _____ ohms.

A. 50
B. 2.5K
C. 132
D. 3.5K

Questions 22-26 refer to the circuit shown in Figure D 1.10-3.

22. This circuit is a _____ amplifier.

A. common base
B. common emitter
C. common collector
D. none of the above

23. The DC-emitter current equals _____ milliamperes.

A. .58
B. .98
C. 1.28
D. 1.48

24. The DC-emitter voltage equals _____ volts.

A. 6.67
B. 2.34
C. 5.98
D. none of the above

25. The voltage gain equals _____.

A. .808
B. .966
C. 1.09
D. 43.0

26. The input impedance of the stage equals _____ ohms.

A. 25.8K
B. 32.3K
C. 109.8K
D. 114.1K

811

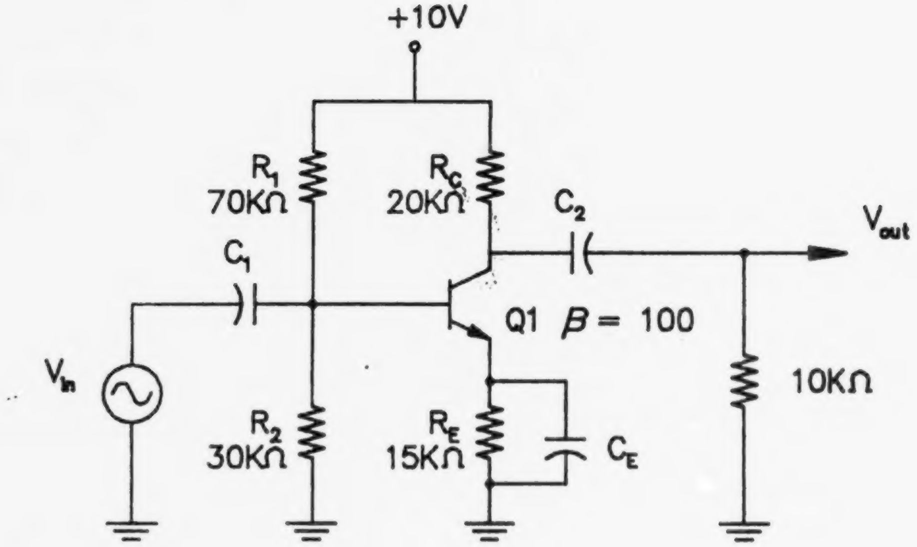

+10V
R1
70KΩ
RC
20KΩ
C2
Vout
C1
Q1 β = 100
Vin
10KΩ
R2
30KΩ
RE
15KΩ
CE

Figure D 1.10-1

812

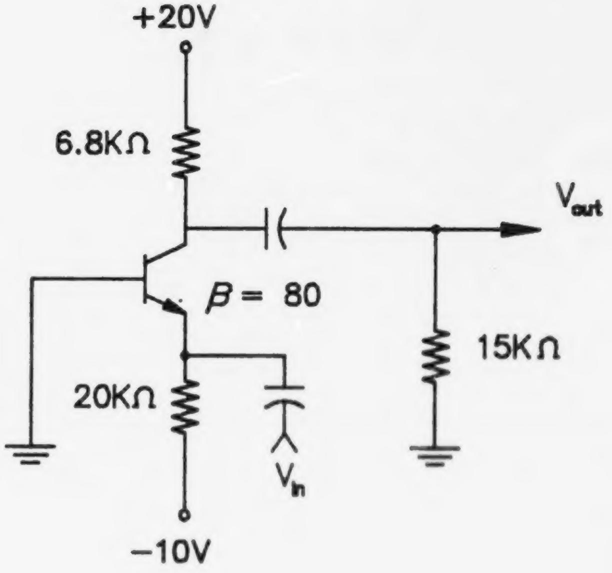

+20V
6.8KΩ
V_{out}
β = 80
15KΩ
20KΩ
V_{in}
−10V

Figure D 1.10-2

EXAM D 1.10 CONT'D.

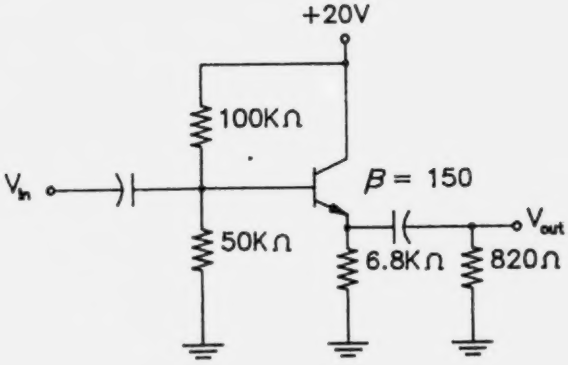

+20V
100KΩ
$\beta = 150$
V_{in}
V_{out}
50KΩ
6.8KΩ
820Ω

Figure D 1.10-3

EXAM D 1.10 CONT'D.

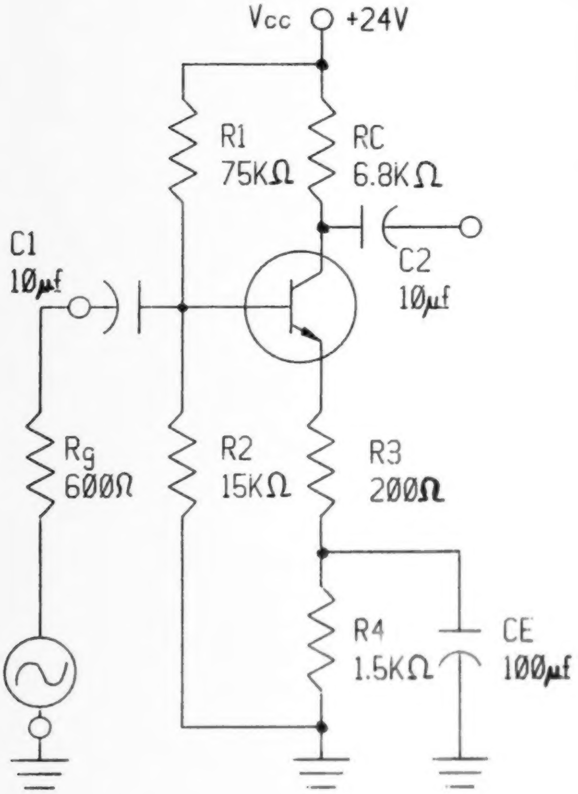

Vcc
+24V
R1
75KΩ
RC
6.8KΩ
C1
10µf
C2
10µf
Rg
600Ω
R2
15KΩ
R3
200Ω
R4
1.5KΩ
CE
100µf

Figure D 1.10-4

27. Symptoms: All DC conditions normal. No AC output. Possible cause:

    A. C_E open
    B. R_3 open
    C. R_2 open
    D. C_2 open

28. Symptoms: No AC output. $V_C = V_{CC}$. V_B = normal. $V_E = 0$. Possible cause:

    A. R_1 increased in resistance
    B. R_2 open
    C. V_{BE} open
    D. R_C open

29. Symptoms: A_e fluctuates with temperature changes.
Possible cause:

A. R_3 decreased in resistance
B. C_E open
C. B-E junction open
D. R_C increased in resistance

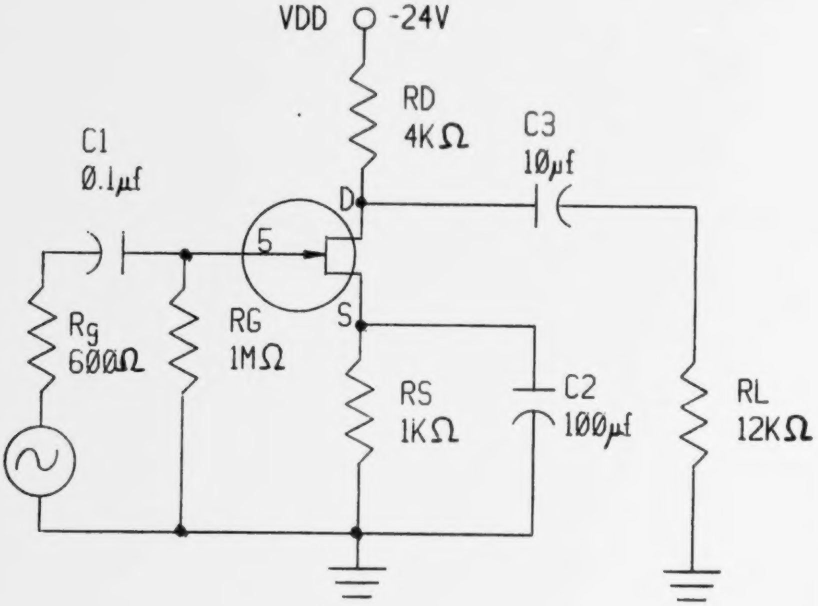

VDD
-24V
RD
4KΩ
C3
10μf
C1
0.1μf
D
5
S
Rg
600Ω
RG
1MΩ
RS
1KΩ
C2
100μf
RL
12KΩ

Figure D 1.10-5

30. Symptom: V_D lower than normal.
Possible cause:

A. R_D decreased in resistance
B. R_S increased in resistance
C. V_{DD} decreased
D. C_2 open

31. Symptoms: No AC output, $V_D = V_{DD}$.
Possible cause:

A. C_2 open
B. FET open
C. C_3 open
D. R_D open

32. Symptoms: Significant decrease in voltage gain. All DC conditions normal. Possible cause:

    A. C_2 open
    B. R_L increased in resistance
    C. C_1 open
    D. D_3 open

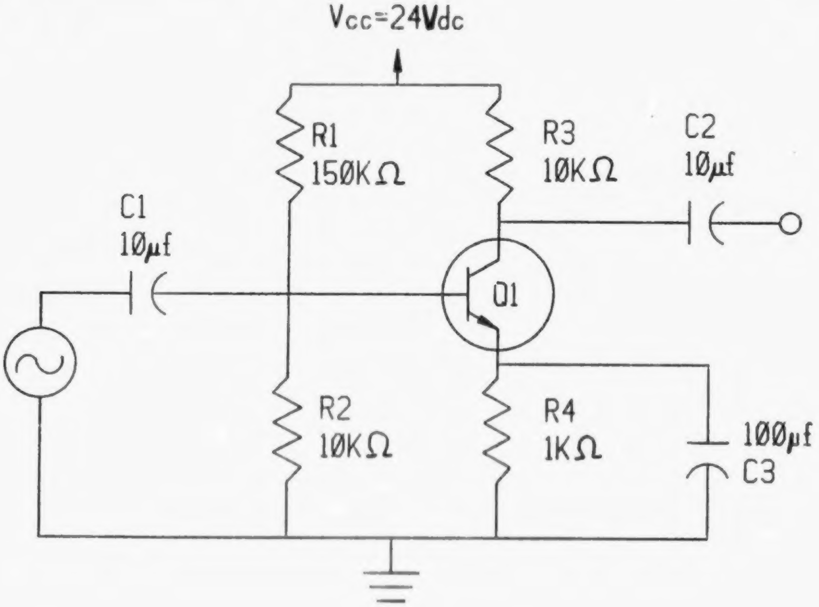

Vcc=24Vdc
R1
150KΩ
R3
10KΩ
C2
10µf
C1
10µf
Q1
R2
10KΩ
R4
1KΩ
100µf
C3

Figure D 1.10-6

33. Symptoms: Low AC output, distortion, V_C lower than normal, V_B and V_E higher than normal. Possible cause:

    A. C_1 open
    B. R_1 increased in resistance
    C. R_3 decreased in resistance
    D. C-B leakage

34. Symptoms: No AC output, V_C = 0 volts, V_B normal. Possible cause:

    A. R_3 open
    B. R_2 open
    C. R_4 open
    D. R_1 open

35. Symptoms: No AC output, $V_B = V_E$, $V_C = V_{CC}$.
Possible cause:

A. C_1 open
B. R_4 open
C. R_1 open
D. R_3 open

EXAM D 1.10

ANSWER KEY

1. B
2. A
3. D
4. C
5. A
6. D
7. C
8. B
9. C
10. C
11. C
12. D
13. C
14. C
15. A
16. B
17. B
18. D
19. C
20. A
21. A
22. C
23. B
24. A
25. B
26. B
27. D
28. A
29. B
30. C
31. B
32. A
33. C
34. A
35. C

ELECTRONICS

ANALYZING ANALOG CIRCUITS

D 2: MULTI-STAGE TRANSISTOR AMPLIFIERS

TASK:	Using a schematic, analyze, construct and troubleshoot multi-stage transistor amplifiers.
PURPOSE:	This learning guide is a continuation of your introduction into the operation and application of electronic devices in analog circuits. This learning guide will explain the terms and processes necessary to assist in the understanding of these applications.
OBJECTIVE:	Given a written examination you will analyze and troubleshoot multi-stage transistor amplifiers.

ESTIMATED CLASS TIME: 15 HOURS

MULTI-STAGE TRANSISTOR AMPLIFIERS

LEARNING STEPS

D 2

READ: Information Sheet D 2.1, "The Common-Emitter Amplifier."

READ: Information Sheet D 2.2, "Multi-Stage Amplifiers."

READ: Information on multi-stage transistor amplifiers in one or more of the references.

COMPLETE: Activity Sheet D 2.3, "Multi-Stage Amplifiers."

REVIEW: Information Sheet D 2.1, and 2.2, and Activity Sheet D 2.3.

COMPLETE: Laboratory performance on multi-stage transistor amplifiers. Contact your instructor.

READ: Information Sheet D 2.4, "Direct-coupled Amplifiers."

READ: Information on direct-coupled transistor amplifiers in one or more of the references.

COMPLETE: Activity Sheet D 2.5, "Direct-coupled Amplifiers."

REVIEW: Information Sheet D 2.4 and Activity Sheet D 2.5.

COMPLETE: Performance Checklist D 2.6.

COMPLETE: Written Exam D 2.7 for mastery of this task.

MULTI-STAGE TRANSISTOR AMPLIFIERS

RESOURCES

D 2

1. ELECTRONIC PRINCIPLES, 3rd Edition, by Malvino (McGraw-Hill, 1984).
2. ELECTRONICS IN INDUSTRY, 5th Edition, by Chute & Chute (McGraw-Hill, 1979).
3. ESSENTIALS OF SOLID STATE ELECTRONICS, by Faber (Wiley, 1985).
4. SEMICONDUCTOR TECHNOLOGY, by Weedon (Energy Concepts, Inc., 1985).
5. SOLID-STATE ELECTRONICS, 2nd Edition, by Rutkowski (Bobbs-Merrill, 1983).
6. Any appropriate electronics textbook

REQUIRED EQUIPMENT

0 - 25 VDC @ 1A Power Supply
0 - 40 VAC @ 1A Isolated Power Supply
0 - 1IMHZ Function Generator
10 MHZ Dual Trace Oscilloscope
Digital Multimeter

INFORMATION SHEET

D 2.1

THE COMMON EMITTER AMPLIFIER

The common emitter amplifier, because of its inherent characteristics, is the most popular and widely used solid state amplifier configuration. These characteristics include relatively high output and input impedances as well as high voltage and power gains. As will be noted in the circuit Figure D 2.1-1 the transistor's emitter is connected to ground and is common to both input and output.

Operation of the transistor as an amplifier requires that proper voltages be applied. This is accomplished through the use of resistors R_1, R_2, R_3, & R_4. Resistors R_1 and R_2 provide the necessary forward bias. R_4 is the emitter swamping resistor which is used for temperature stabilization.

There is a 180° phase shift between input and output voltages (AC signal voltage). Note that a positive-going input signal will reduce forward bias on the transistor. This in turn will reduce collector current, thus causing the voltage drop across R_3 to decrease. A decreasing voltage drop across R_3 indicates a negative-going output voltage.

Capacitor C_1 is used for emitter bypassing. An increasing current flow through the transistor will cause an increased voltage drop across the emitter swamping resistor R_4. An increased drop across R_4 will drive the emitter more negative which effectively reduces forward bias on the base. Because the increasing voltage across R_4 is an alternating or changing voltage, the bypass capacitor will shunt this AC component around the resistor, thus reducing voltage changes across R_4. Any bypass capacitor is effectively a short circuit for AC. The main objective for using this capacitor is to increase the gain of the amplifier. (Using R_4 causes a loss in gain due to varying bias with input signal. Effective by-passing will help to reduce this loss.)

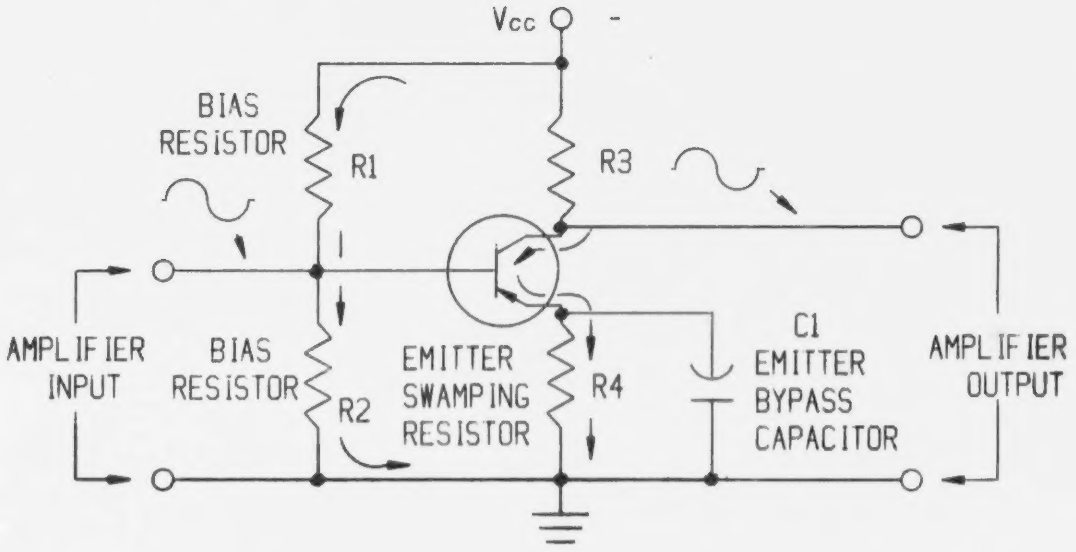

Vcc
-
BIAS RESISTOR
R1
R3
AMPLIFIER INPUT
BIAS RESISTOR
R2
EMITTER SWAMPING RESISTOR
R4
C1
EMITTER BYPASS CAPACITOR
AMPLIFIER OUTPUT

Figure D 2.1-1

Input impedance is the load actually seen by the signal source such as a signal generator, microphone, phono cartridge, or amplifier stage feeding the CE (common-emitter) circuit. Factors affecting input impedance include the transistor's base-emitter junction, forward resistance, bias resistors R_1 and R_2, swamping resistor R_4, transistor Beta and the emitter bypass capacitor (if used). R_4 will increase the input impedance while bias resistors R_1 and R_2 and the bypass capacitor will reduce it. Note that R_2 is actually in parallel with R_1-R_4 thus providing an additional current path in the input. Closer inspection will also reveal that R_1 is also in parallel with the input since the battery or power source is assumed to have zero impedance to the signal. (As far as the signal is concerned, the top of R_1 is shorted to the bottom of R_2). However, in practical situations, the resistance of R_1 is very high and for all practical purposes, the effect of R_1 upon the input impedance can be neglected.

C_1 is parallel with R_4 and reduces the AC impedance of the emitter circuit by a factor of approximately 1/10.

Two simple methods may be used in determining input impedance of an actual circuit. One method, involving the use of Ohm's Law, is accomplished by measuring the AC (signal) base current and the AC (signal) voltage at the input of the amplifier. The formula $Z_{in} = V_{in}/I_{in}$ gives the input impedance.

A simpler method requires feeding the amplifier output signal to a CRO or AC VTVM, then inserting a potentiometer in series with the signal INPUT and using this control to reduce the amplifier output to 1/2 its original value. In this condition the amplifier and series resistance are dropping equal amounts of signal voltage and therefore must be of equal impedance. At this point, the potentiometer is removed from the circuit and its set resistance, being equal to Z_{in}, is measured with an ohmmeter.

Output impedance is the internal circuit impedance or resistance seen by the succeeding load or circuit being fed by the amplifier output. This output impedance actually shows up as a resistance in series with the circuit output. See Figure D 2.1-2.

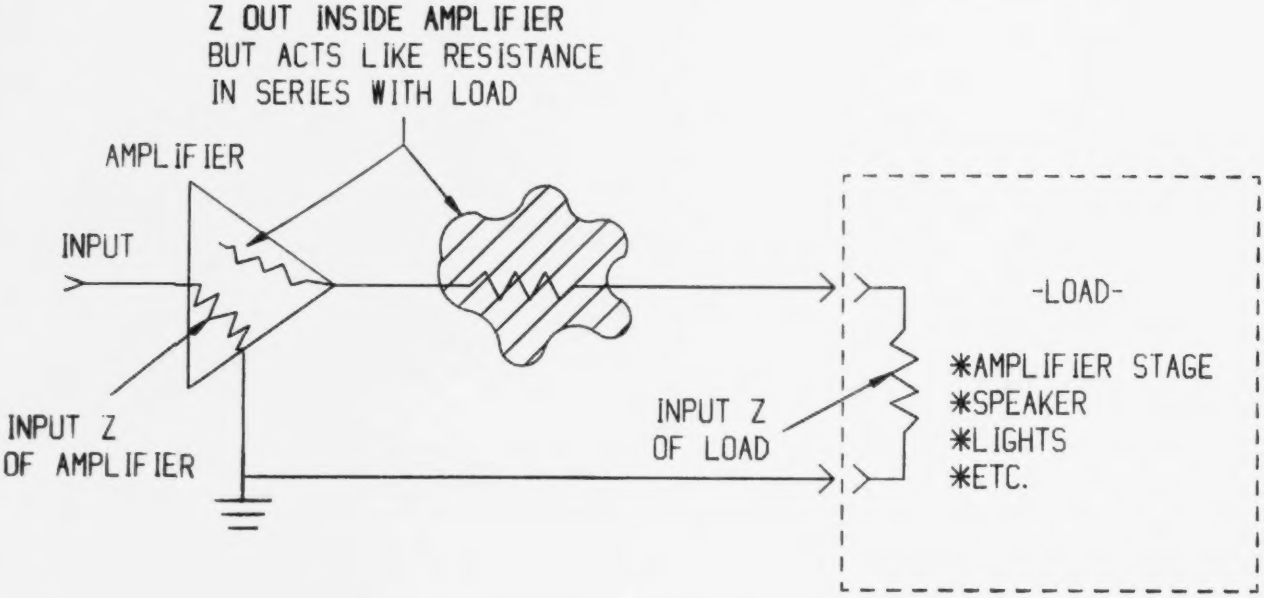

Z OUT INSIDE AMPLIFIER
BUT ACTS LIKE RESISTANCE
IN SERIES WITH LOAD
AMPLIFIER
INPUT
INPUT Z
OF AMPLIFIER
INPUT Z
OF LOAD
-LOAD-
*AMPLIFIER STAGE
*SPEAKER
*LIGHTS
*ETC.

Figure D 2.1-2

As can be seen in Figure D 2.1-2, a load which draws current will cause a portion of the amplifier output voltage to be dropped across the internal output impedance. As most transistors are current operated devices, it will be found that maximum power transfer to the load will occur when the load impedance is equal to the driving output impedance. This is known as matching impedances. In this matched condition, the amplifier output voltage will be equal to one-half the open circuit (no load) voltage.

Voltage gain for an amplifier is found by signal voltage output by the signal voltage input. Power gain can be determined by several methods.

(1) $$A_P = \frac{P_{out}}{P_{in}}$$

(2) This method makes use of the standard I^2R power formula.

$$A_P = \frac{I_{out}^2 Z_{out}}{I_{in}^2 Z_{in}}$$

(3) This method makes use of the standard V^2/R power formula.

$$A_P = \frac{V_{out}^2/Z_{out}}{V_{in}^2/Z_{in}}$$

The frequency response of an amplifier tells us how much the circuit amplifies each frequency arriving at the input. Ideally, the amplifier should provide an equal or constant gain for all frequencies. the transistor itself will amplify down to DC. However, it does have an upper frequency cut-off which is determined primarily by the thickness of the base region, shunt capacitance within the transistor, circuit wiring, and transformer losses if transformer coupling is used. A frequency response curve is obtained by driving the amplifier with a constant voltage while varying the frequency. Amplifier output voltage is measured at each frequency and plotted on a graph. See Figure D 2.1-3.

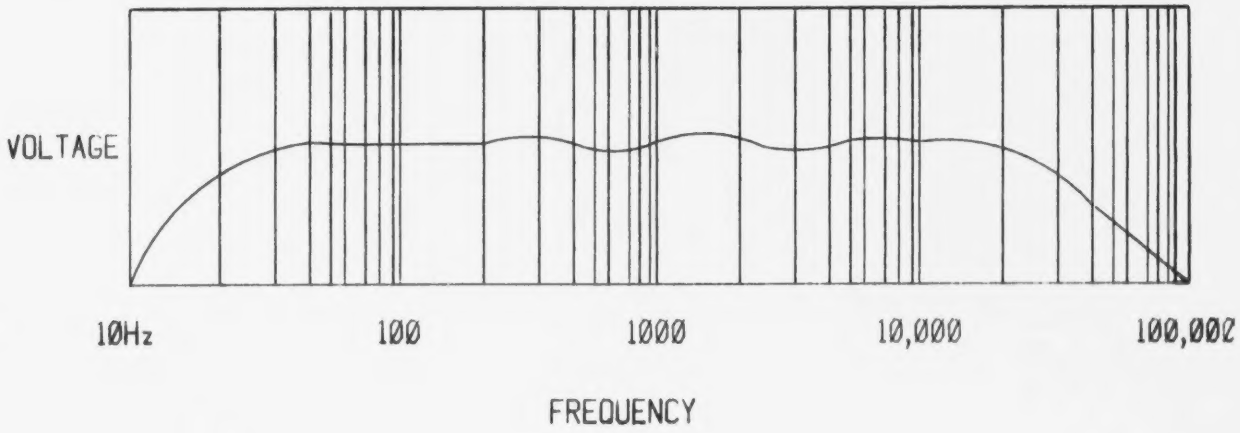


Figure D 2.1-3

The response of low frequencies in an amplifier is limited by the coupling device employed. In the circuit shown in Figure D 2.1-4, a capacitor is used to pass the AC signal component from the first stage to the second. Note that coupling capacitor C_c is actually in series with the input to the second amplifier stage. Capacitive reactance in C_c shows up as resistance in the circuit, its actual amount being inversely proportional to frequency. Thus, for a lower frequency, an increase of capacitive reactance will reduce the current flow into the following stage while dropping a larger share of the signal voltage across the capacitor, resulting in lower power transfer to the following stage. Utilization of DC (direct coupling) coupling will extend the frequency response down to DC.

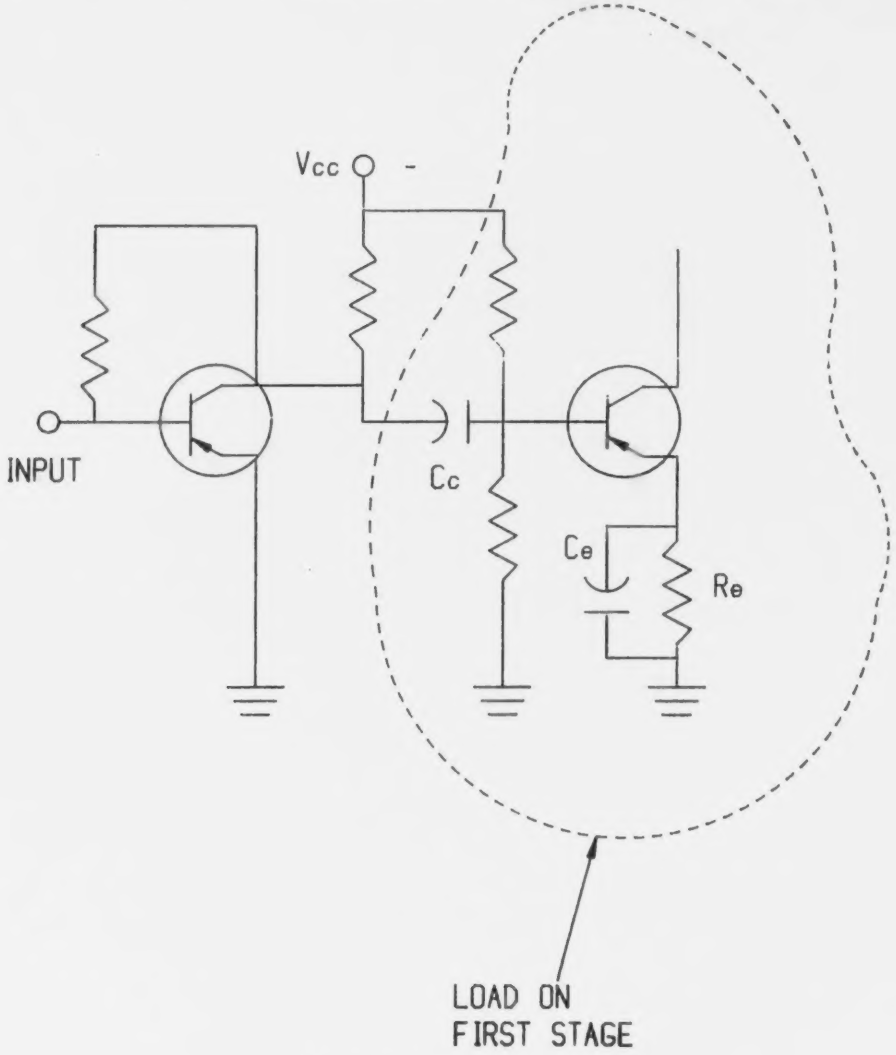


Figure D 2.1-4

INFORMATION SHEET

D 2.2

MUTLI-STAGE AMPLIFIERS

When there is need for more amplification than can be provided with a single transistor, several amplifiers are connected in series. Each transistor represents a stage of amplification. When connecting two or more transistor stages together, two points must be considered. The first is the need to keep the DC voltages (bias) of one transistor from affecting the bias on another. The second requirement is that the signal be passed from one stage to the other with minimum loss and distortion.

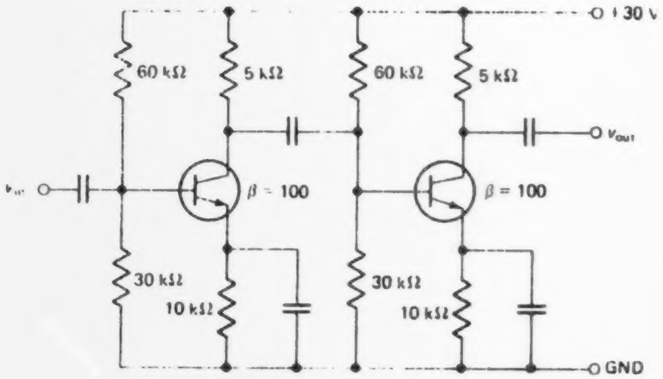
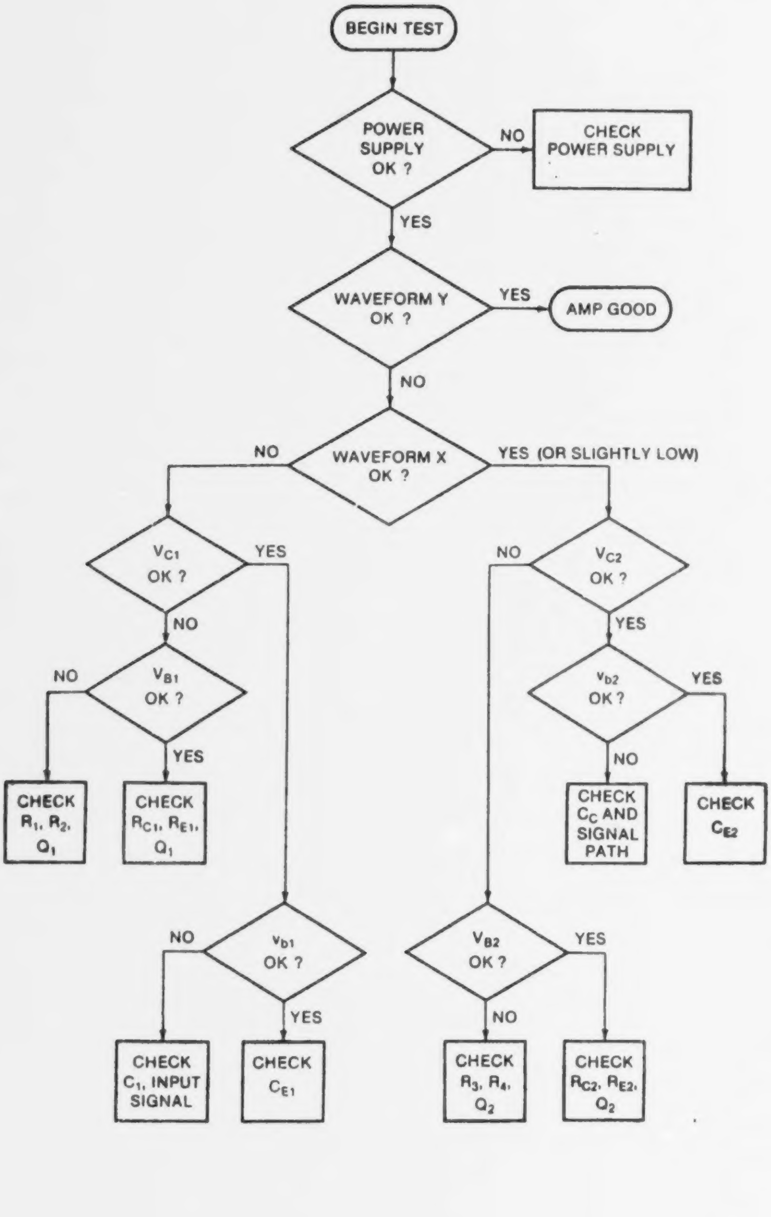


Figure D 2.2-1

The Figure D 2.2-1 above is the schematic diagram of a two-stage capacitively-coupled amplifier. The advantage of this type of amplifier is that each stage may be identical. The capacitor connecting each stage together is called a coupling capacitor. The function of a coupling capacitor is to pass the desired AC signal while preventing the DC bias voltages from affecting each other. Capacitive coupling is very effective unless the signals to be amplified are DC or very low frequency AC signals. Similar results may be obtained using transformers to couple the two stages. Transformers are capable of providing a better impedance match, but they are physically larger and more expensive than capacitors.

When testing or troubleshooting a multi-stage amplifier such as the one above, use a logical approach. The first step is to use your built-in test equipment. Use your eyes and nose to look for such problems as burned, overheated, or physically damaged parts. Don't forget to check for a blown fuse. If the result of your check is empty, get your electronic test equipment and begin the electrical testing. The flowchart below lists the steps necessary to troubleshoot the amplifier above.

MULTI-STAGE TROUBLESHOOTING FLOW CHART


BEGIN TEST
POWER SUPPLY OK ?
NO
CHECK POWER SUPPLY
YES
WAVEFORM Y OK ?
YES
AMP GOOD
NO
WAVEFORM X OK ?
NO
YES (OR SLIGHTLY LOW)
V_{C1} OK ?
YES
NO
V_{B1} OK ?
NO
YES
CHECK R_1, R_2, Q_1
CHECK R_{C1}, R_{E1}, Q_1
v_{b1} OK ?
NO
YES
CHECK C_1, INPUT SIGNAL
CHECK C_{E1}
V_{C2} OK ?
NO
YES
v_{b2} OK ?
YES
NO
CHECK C_C AND SIGNAL PATH
CHECK C_{E2}
V_{B2} OK ?
YES
NO
CHECK R_3, R_4, Q_2
CHECK R_{C2}, R_{E2}, Q_2

INFORMATION SHEET D 2.2 CONT'D.

The frequency of cascaded stages is affected by the coupling element. The capacitive reactance of the coupling capacitor are considered to be negligible at the operating frequencies of the amplifier. At DC and low AC frequencies, the reactance becomes too high to ignore. The input resistance of the amplifier stage is the parallel resistance of the bias resistors and the input resistance to the base of the transistor. The lower frequency half-power point occurs at:

$$f_1 = \frac{1}{2\pi R_t C}$$

Just as the coupling capacitor limits the lower frequency response of the amplifier, the stray capacitance of the amplifier determines the upper frequency half-power point. The resistance is collector resistance in parallel with the input resistance of the next stage. This occurs at:

$$f_2 = \frac{1}{2\pi R_{eq} C_3}$$

With the extra gain available in multi-stage amplifiers, negative feedback is used to reduce the distortion and provide gain control. Although negative feedback reduces the overall gain of an amplifier, it does increase the stability of the amplifier. This prevents the amplifier from oscillating.

The schematic, Figure D 2.2-2 , illustrates a simple direct-coupled amplifier with feedback. There are no coupling capacitors between the stages and the input and output. This circuit is capable of amplifying frequencies from DC to the upper cutoff frequency. The collector biasing of the first transistor becomes the base bias for the second stage. Because of this arrangement, it is very important that the bias point remain constant.

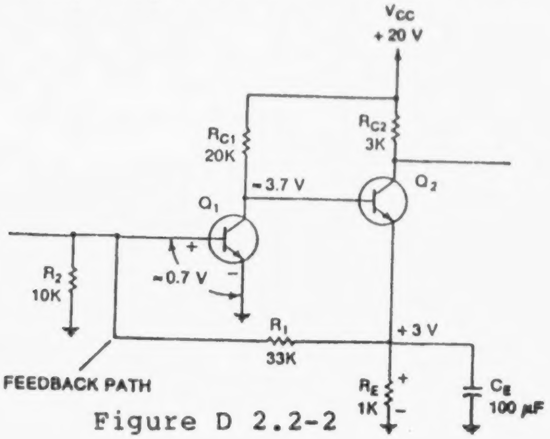


Figure D 2.2-2

To help maintain a stable bias it is necessary to use negative feedback. Feedback in this circuit controls the gain of the circuit, stabilizes the circuit, and reduces the distortion of the amplifier.

ACTIVITY SHEET

D 2.3

MULTI-STAGE AMPLIFIERS

1. Define: multistage amplifier, feedback, direct-coupled amplifier, differential amplifier, common-emitter amplifier, capacitive-coupled amplifier, transformer-coupled amplifier, impedance-matching, and tuned transformer.

2. Explain the operation of a 2-stage capacitively-coupled amplifier.

3. Explain the operation of a 2-stage direct-coupled amplifier.

4. Explain the advantages and disadvantages of feedback.

5. How is the voltage gain of an amplifier determined?

ACTIVITY SHEET D 2.3

ANSWER SHEET

1. See Text
2. See Text. It is important that there is poor low frequency response due to capacitors.
3. See Text. It is important to stress DC bias voltages.
4. Reduces distortion; reduces gain
5. $A_v = V_o/V_i$

ACTIVITY SHEET

D 2.4

DIRECT-COUPLED AMPLIFIERS

For maximum reliability and economy of design, the number of components in a circuit should be kept to a minimum. Direct coupling between stages accomplishes this goal. More importantly, direct-coupled amplifiers are capable of amplifying direct current signals.

The first step in the designing of a direct-coupled circuit as shown in Figure D 2.4-1 is to determine the bias voltage for Q_2. Because the circuit is direct-coupled you must look at the voltages on Q_1.

$$V_{B_2} = V_{C_1} = V_{E_1} + V_{CE_1}$$

Thus you arrive at an emitter voltage for Q2 equal to

$$V_{E_2} = V_{B_2} - V_{BE}$$

The voltage across the collector resistor R_5 is

$$V_{R_5} = V_{CC} - V_{EZ} - V_{CE_2}$$

As discussed earlier, suitable voltage levels for small signal amplifiers are a collector to emitter voltage of three volts, and an emitter voltage of about five volts. To keep the load from upsetting the circuit, the collector resistor should be kept as small as possible, ten times smaller than the load if the transistor is capable of handling the current. If not, adjust the value of the collector resistor accordingly.

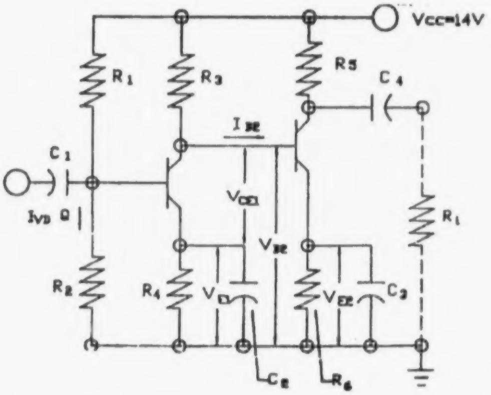


Figure D 2.4-1

Q_1 + Q_2 $h_{fe} = 50$

& $h_{ie} = .5K\Omega$

$R_L = 40K\Omega$

$f_1 = 50Hz$

ACTIVITY SHEET D 2.4 CONT'D.

Figure D 2.4-1 shows two NPN transistors connected in a direct-coupled circuit. Let's determine a set of workable resistor values for that circuit using the values shown.

Using the typical values for this type of circuit, let V_{E1} = 5V, and V_{CE1} and V_{CE2} both equal 3V. Once this has been established, we can now begin to calculate the rest of the values.

$V_{B2} = V_{C1} = V_{E1} + V_{CE1}$
$= 5V + 3V$
$= 8V$

$V_{E2} = V_{B2} - V_{BE}$
$= 8V - .7V$
$= 7.3V$

$V_{R5} = V_{CC} - V_{E2} - V_{CE2}$
$= 14V - 7.3V - 3V$
$= 3.7V$

To minimize load effect, $R_5 = R_L/10$ which is

$= 40k\Omega/10$
$= 4k$ ohms. The closest value is 3.9k ohms.

$I_{C2} = V_{R5}/R_5$
$= 3.7V/3.9k\Omega$
$= 950\ \mu A$

$R_6 = V_{E2}/I_{C2}$
$= 7.3/950\mu A$
$= 7.7k$ ohms. The standard value to use is 8.2k ohms. To reduce future calculation error, recalculate I_{C2} using the new value.

$I_{C2} = V_{E2}/R_6$
$= 7.3V/8.2k\Omega$
$= 890uA$ for the actual value of I_{C2}

Because both transistors are the same, and to simplify calculations, let's assume that I_{C1} and I_{C2} will be the same and we know I_{C2} is approximately 1mA.

$V_{R3} = V_{CC} - V_{C1}$
$= 14V - 8V$
$= 6V$

ACTIVITY SHEET D 2.4 CONT'D.

$R_3 = V_{R3}/I_{C1}$
$= 6V/1mA$
$= 6k$ ohms. Once again, the standard value is 5.6k ohms, and recalculating I_{C1} gives better accuracy.

$I_{C1} = V_{R3}/R_3$
$= 6V/5.6k\Omega$
$= 1.07mA$

$R_4 = V_{E1}/I_{C1}$
$= 5V/1.07mA$
$= 4.7k$ ohms. Happens to be a standard value.

$V_{B1} = V_{E1} + V_{BE}$
$= 5V + .7V$
$= 5.7V$

Remember that for stability, I_{VO} should be much larger than I_B and $I_C = h_{FE}$ times I_B. So let

$I_{VD} = V_{C1}/10$
$= 1.07mA/10$
$= .1mA$

$R_2 = V_{B1}/I_{VD}$
$= 5.7V/.1mA$
$= 57k$ ohms. Use 56k ohms as the standard value and recalculate I_{VD}.

$I_{VD} = V_{B1}/R_2$
$= 5.7V/56k\Omega$
$= .102mA$

$R_1 = (V_{CC} - V_{B1})/I_{VD}$
$= (14V - 5.7V)/.102mA$
$= 81k$ ohms. Use 82k ohms, a standard value.

The DC bias design is complete. Review it until you understand the process.

Notice that there are capacitors connected in the circuit. Let's determine the values for these capacitors using the information given in the previous example.

$Z_i = R1||R2||h_{ie}$
$= 82k\Omega|| 68k\Omega||500\Omega$
$= 493$ ohms

For maximum signal transfer, the reactance must be at least 10 times smaller then the input impedance. Therefore,

ACTIVITY SHEET D 2.4 CONT'D.

$X_{C1} = Z_1/10$
$= 493\ /10$
$= 49.3$ ohms

Remembering that $X_C = 1/(2\pi fC)$

$C_1 = 1/2\pi\ f_i\ X_{C1}$
$= 1/6.28 \text{ X } 50 \text{ X } 49.3$
$= 64.5\mu F$. Use $75\mu F$ as the closest standard value.

Let's have the bypass capacitors the same size for both stages. This results in X_{C2} and X_{C3} being the same value. This will also result in C_2 and C_3 being equal in value.

$X_{C2} = h_{ie}/1 + h_{fe}$
$= 500/51$
$= 9.8$ ohms. Remember this is also the value of X_{C3}.

$C_2 = 1/2\pi\ f_1\ X_{C2}$
$= 1/6/28 \text{ X } 50 \text{ X } 9.8$
$= 331\ \mu F$. Use $330\mu F$ as the closest standard value.

$X_{C4} = R_L/10$
$= 40k\Omega/10$
$= 4k$ ohms

$C_4 = 1/2\pi\ f_1\ X_{C4}$
$= 1/6/28 \text{ X } 50 \text{ X } 4k\Omega$
$= .80\mu F$. Use $1\mu F$ as the closest standard value.

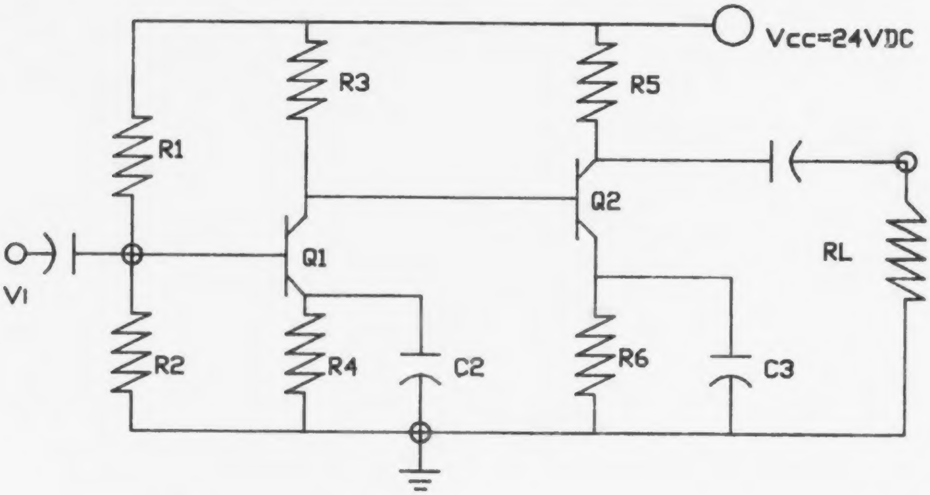
ACTIVITY SHEET

D 2.5

DIRECT-COUPLED AMPLIFIERS

1. Define: frequency response, lower cutoff, upper cutoff.

2. Given the following parameters, determine the correct component values of the circuit shown below. Q_1 and Q_2 $h_{fe} = 100$, $h_{ie} = .5k$ ohms, $R_L = 1$ k ohms, and $f_1 = 100$Hz.


Vcc=24VDC
R3
R5
R1
Q2
Q1
RL
Vi
R2
R4
C2
R6
C3

ACTIVITY SHEET D 2.5

ANSWER SHEET

1. See text for definitions.

2. Using the typical values for this type of circuit, let V_{E1} = 8V, and V_{CE1} and V_{CE2} both equal 4V. Once this has been established, we can now begin to calculate the rest of the values.

$$\begin{aligned} V_{B2} &= V_{C1} = V_{E1} + V_{CE1} \\ &= 8V + 4V \\ &= 12V \end{aligned}$$

$$\begin{aligned} V_{E2} &= V_{B2} - V_{BE} \\ &= 12V - .7V \\ &= 11.3V \end{aligned}$$

$$\begin{aligned} V_{R5} &= V_{CC} - V_{E2} - V_{CE2} \\ &= 24V - 11.3V - 4V \\ &= 8.7V \end{aligned}$$

To minimize load effect, $R_5 = R_L/10$ which is

$= 1k\Omega/10$
$= 100$ ohms. Which is a standard value.

$$\begin{aligned} I_{C2} &= V_{R5} \\ &= 8.7V/100 \\ &= 87 \text{ mA} \end{aligned}$$

$$\begin{aligned} R_6 &= V_{E2}/I_{C2} \\ &= 11.3/86mA \\ &= 130 \text{ ohms.} \end{aligned}$$

The standard value to use is 120 ohms. To reduce future calculation error, recalculate I_{C2} using the new value.

$$\begin{aligned} I_{C2} &= V_{E2}/R_6 \\ &= 11.3V/120\Omega \\ &= 94mA \text{ for the actual value of } I_{C2}. \end{aligned}$$

Because both transistors are the same and to simplify calculations let's assume that I_{C1} and I_{C2} will be the same and we know I_{C2} is approximately 94mA.

$$\begin{aligned} V_{R3} &= V_{CC} - V_{C1} \\ &= 24V - 12V \\ &= 12V \end{aligned}$$

ACTIVITY SHEET D 2.4 CONT'D.

$R_3 = V_{R3}/I_{C1}$
$= 12V/94mA$
$= 128$ ohms. Once again, the standard value is 120 ohms, and recalculating I_{C1} gives better accuracy.

$I_{C1} = V_{R3}/R_3$
$= 12V/120$
$= 100mA$

$R_4 = V_{E1}/I_{C1}$
$= 8V/100mA$
$= 80$ ohms. 81 ohms is the standard value.

$V_{B1} = V_{E1} + V_{BE}$
$= 8V + .7V$
$= 8.7V$

Remember that for stability, I_{VD} should be much larger than I_B and $I_C = h_{FE}$ times I_B. So let

$I_{VD} = I_{C1}10$
$= 100ma/10$
$= 10mA$

$R_2 = V_{B1}/I_{VO}$
$= 8.7V/10mA$
$= 870$ ohms. Use 820 ohms as the standard value and recalculate.

$V_{B1} = V_{B1}/R_2$
$= 8.7V/820$
$= 10.6ma$

$R_1 = (V_{CC} - V_{B1})/I_{VO}$
$= (24V - 8.7V)/10.6mA$
$= 1443$ ohms. Use 1500 ohms, a standard value.

$Z_i = R1||R2||h_{ie}$
$= 1.5k\Omega|| 800\Omega||500\Omega$
$= 257$ ohms

For maximum signal transfer, the reactance must be at least 10 times smaller then the input impedance. Therefore

$X_{C1} = Z_i/10$
$= 257\Omega/10$
$= 25.7$ ohms

Remembering that $X_C = 1/(2\pi fC)$

ACTIVITY SHEET D 2.4 CONT'D.

$C_1 = 1/2\pi\ f_1\ X_{C1}$
$= 1/(6.28 \times 100 \times 25.7)$
$= 62\mu F$. Use $75\mu F$ as the closest standard value.

Both bypass capacitors will be the same size.

$X_{C2} = h_{ie}/(1 + h_{fe})$
$= 500/101$
$= 4.95$ ohms. Remember this is also the value for X_{C3}.

$C_2 = 1/2\pi\ f_1\ X_{C}2$
$= 1/6.28 \times 100 \times 4.95$
$= 322\ \mu F$. Use $330\mu F$ as the closest standard value.

$X_{C4} = R_L/10$
$= 1k\ /10$
$= 100$ ohms

$C_4 = 1/2\pi\ f_i\ X_{C4}$
$= 1/6.28 \times 100 \times 100$
$= 15.9\mu F$. Use $15\mu F$ as the closest standard value.

PROGRAM: ELECTRONICS

TASK: DIRECT-COUPLED AMPLIFIERS

TASK #: D 2.6

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

USING A SCHEMATIC, ANALYZE, CONSTRUCT AND TROUBLESHOOT MULTI-STAGE TRANSISTOR AMPLIFIERS.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 5 out of 6 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 5 out of 6 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed

ELECTRONICS

DIRECT-COUPLED AMPLIFIERS

D 2.6

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the required equipment used?	Y N
*2.	Was the required data recorded?	Y N
3.	Was the equipment used according to specifications?	Y N
*4.	Were all safety precautions followed?	Y N
5.	Was equipment returned to the proper storage area?	Y N
		Y N
*6.	Was the experiment summarized properly?	Y N

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

DIRECT-COUPLED AMPLIFIERS

EXAM

D 2.7

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Direct-Coupled Amplifiers. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 16 out of 20 items correctly, 80%.

DIRECT-COUPLED AMPLIFIERS

EXAM

D 2.7

1. Positive feedback is used to increase the bandwidth of an amplifier.

   A. True
   B. False

2. The input impedance to a stage is always less than the input impedance of the transistor used in the construction of the stage.

   A. True
   B. False

3. Direct-coupled amplifiers can amplify only DC signals.

   A. True
   B. False

4. Negative feedback decreases the stability of an amplifier.

   A. True
   B. False

5. The upper half-power point frequency of an amplifier is limited by the size of the emitter bypass capacitor.

   A. True
   B. False

6. The larger the percentage of output signal feedback, the less distortion in the amplifier.

   A. True
   B. False

7. The first thing to do when troubleshooting an amplifier is to look it over closely.

   A. True
   B. False

8. The size of the coupling capacitor determines the lower half-power point frequency of the amplifier.

   A. True
   B. False

9. A shorted coupling capacitor will not effect the DC bias voltages in a multi-stage amplifier.

   A. True
   B. False

10. An open coupling capacitor in a multi-stage amplifier will not effect the DC bias voltages.

   A. True
   B. False

For problems 11-13 refer to Figure D 2.7-1.

11. V_e of Q2 is lower than normal, the AC output of Q2 is distorted and reduced in amplitude; the most likely cause is:

   A. R_2 increased in resistance
   B. R_6 opened
   C. R_1 increased in resistance
   D. C_2 is leaky

12. There is low AC output from Q2, no distortion, and V_e is higher than normal; the most likely cause is:

   A. R_4 decreased in resistance
   B. C_2 is leaky
   C. R_3 decreased in resistance
   D. R_1 open

13. There is low AC output on Q2, improved linearity, and all DC voltages are normal; the most likely cause is:

   A. C_1 open
   B. C_2 open
   C. C_3 open
   D. R_6 open

For questions 14 AND 15 refer to Figure D 2.7-2.

14. V_{R6} is lower than normal, V_c on Q1 is lower than normal, and there is increased circuit gain; the most likely cause is:

   A. R_3 increased in resistance
   B. R_1 increased in resistance
   C. C_5 leaky
   D. C_6 leaky

15. There is severe distortion, clipping in the output, reduced AC output; the most likely cause is:

    A. R_3 increased in resistance
    B. R_7 decreased in resistance
    C. R_1 open
    D. R_4 open

16. If a common emitter transistor amplifier is driven toward saturation, V_c will:

    A. be higher than normal
    B. be lower than normal
    C. remain unchanged
    D. become zero volts

17. The AC output of a common emitter amplifier is clipped on the positive alternation. This is caused by:

    A. saturation limiting
    B. cutoff limiting
    C. insufficient input signal
    D. can not be determined from given information

18. Distortion is present in an audio amplifier. Which single piece of test equipment listed below would best help you to troubleshoot the problem?

    A. voltmeter
    B. sweep generator
    C. oscilloscope
    D. logic probe

19. The gain of a multistage amplifier is:

    A. equal to the sum of the gains of the individual stages
    B. equal to the product of the gains of the individual stages
    C. less than the gain of any one stage
    D. limited by the coupling capacitor size

20. Direct-coupled amplifiers have:

    A. poorer low frequency response than capacitance-coupled amplifiers
    B. poorer low frequency response than transformer-coupled amplifiers
    C. little sensitivity to bias drift
    D. better low frequency response than capacitance-coupled amplifiers.

EXAM D 2.7 CONT'D.

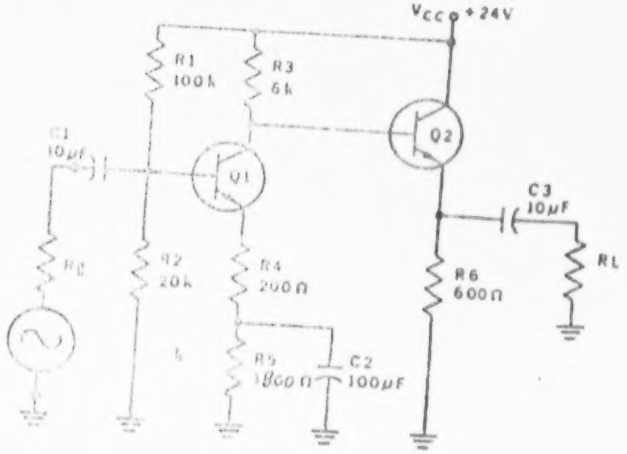

VCC +24V
R1
100k
R3
6k
C1
10μF
Q1
Q2
C3
10μF
RL
Rg
R2
20k
R4
200Ω
R6
600Ω
R5
1800Ω
C2
100μF

Figure D 2.7-1

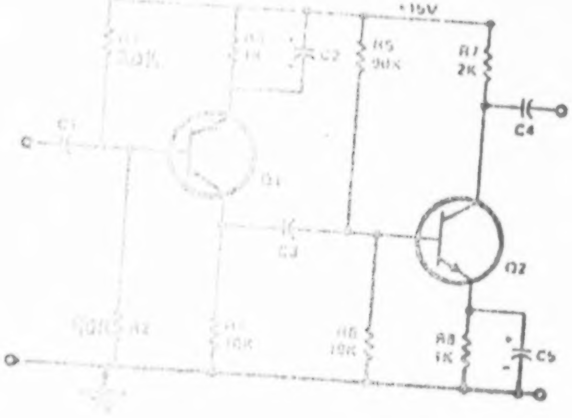

+15V
R3
1K
C2
R5
90K
R7
2K
C1
C4
Q1
C3
Q2
R2
R4
10K
R6
10K
R8
1K
C5

Figure D 2.7-2

EXAM D 2.7

ANSWER KEY

1. B
2. A
3. B
4. B
5. B
6. A
7. A
8. A
9. B
10. A
11. D
12. C
13. B
14. D
15. A
16. B
17. D
18. C
19. B
20. D

ELECTRONICS

ANALYZING ANALOG CIRCUITS

D 3: POWER SUPPLIES

TASK:	Using a schematic, analyze, construct and troubleshoot power supplies.
PURPOSE:	All electronic devices require a power source. There are special circuits called power supplies that provide and regulate the power delivered to the rest of the device. This learning guide will explain the terms and processes necessary to assist in the understanding of these circuits.
OBJECTIVE:	Given a written examination you will be able to analyze and troubleshoot basic power supplies.

ESTIMATED CLASS TIME: 15 HOURS

POWER SUPPLIES

LEARNING STEPS

D 3

READ:	Information Sheet D 3.1, "Rectifiers."
READ:	Information on basic rectifiers in one or more of the references.
COMPLETE:	Activity Sheet D 3.2, "Rectifiers."
READ:	Information Sheet D 3.3, "Filters."
COMPLETE:	Activity Sheet D 3.4, "Filters."
REVIEW:	Information Sheets D 3.1, D 3.2 and Activity Sheets D 3.2 and D 3.4.
COMPLETE:	Laboratory performance on rectifiers and filters. Contact your instructor.
COMPLETE:	Performance checklist D 3.5
COMPLETE:	Written examination D 3.6 for mastery of this task.

ADVANCED STUDY

READ:	Information Sheet D 3.7, "Regulators."
READ:	Information on regulators in one or more of the references.
COMPLETE:	Activity Sheet D 3.8, "Regulators."
REVIEW:	Information Sheet D 3.7, and Activity Sheet D 3.8
COMPLETE:	Laboratory performance on regulators. Contact your instructor.
COMPLETE:	Performance Checklist D 3.9
COMPLETE:	Written Exam D 3.10 for mastery of this task.

POWER SUPPLIES

RESOURCES

D 3

1. ELECTRONIC PRINCIPLES, 3rd Edition, by Malvino (McGraw-Hill, 1984).
2. ELECTRONICS IN INDUSTRY, 5th Edition, by Chute & Chute (McGraw-Hill, 1979).
3. ESSENTIALS OF SOLID STATE ELECTRONICS, by Faber (Wiley, 1985).
4. SEMICONDUCTOR TECHNOLOGY, by Weedon (Energy Concepts, Inc., 1985).
5. SOLID-STATE ELECTRONICS, 2nd Edition, by Rutkowski (Bobbs-Merrill, 1983).
6. Any appropriate electronics textbook

REQUIRED EQUIPMENT

0 - 25 VDC @ 1A Power Supply
0 - 40 VAC @ 1A Isolated Power Supply
0 - 1IMHZ Function Generator
10 MHZ Dual Trace Oscilloscope
Digital Multimeter

INFORMATION SHEET

D 3.1

RECTIFIERS

Most electronic devices require direct current for proper operation. Some devices are battery powered, thus providing the proper power. The rest of the devices are powered from the utility power system. This supplies 120 VAC at 60 Hertz. To enable electronic systems to function properly, this alternating current must be converted to direct current. The device for accomplishing this is the rectifier.

The component in the rectifier circuit that does the actual rectification is a diode. Figure D 3.1-1 below illustrates the typical schematic diagram and output waveform of rectified alternating current. The polarity of the current is the same as that produced by a battery.

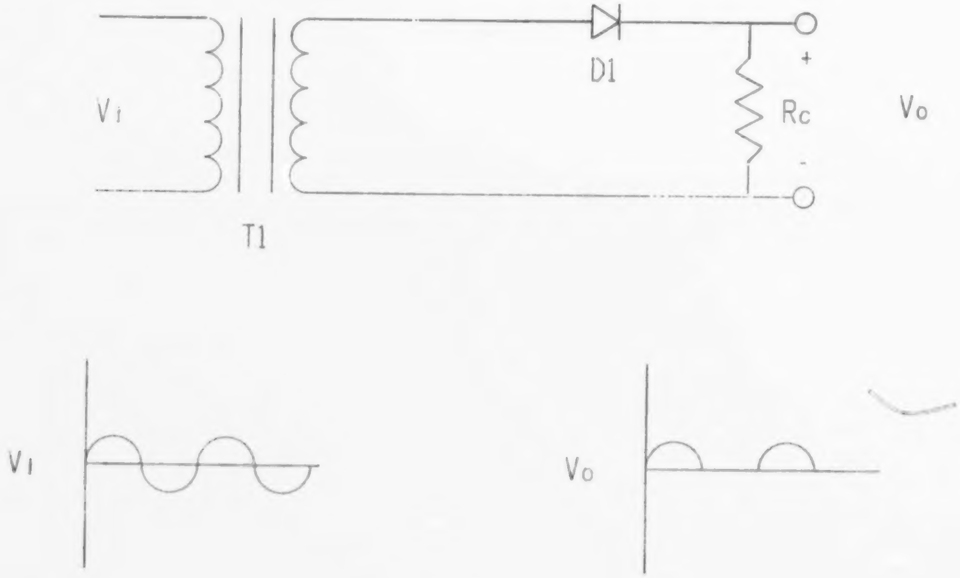


Figure D 3.1-1

The disadvantage of rectified DC is that it produces a pulsating current flow. The current flows in one direction only, but it is continually starting and stopping. If this type of electricity were to operate a television or radio there would be a loud buzzing in the audio. There are two basic types of rectifiers, half-wave and full-wave. And there are two different types of full-wave rectifiers, a center-tapped full-wave, and a full-wave bridge.

The simplest form of rectifier circuit is the half-wave rectifier circuit shown in Figure D 3.1-2. This circuit consists of a transformer, a diode, and the load, represented by a resistor. Shown with the rectifier are input and output waveforms. This type of rectifier circuit is economical and easy to construct, but it has two major shortcomings. Because the diode only passes one-half of the input waveform, the maximum efficiency of the circuit is 50%. Also because the circuit is on half the time and off half the time it has a very high ripple factor. Ripple factor is the amount of AC contained with the DC. The ripple frequency of a half-wave rectifier will be equal to the frequency of the input voltage.

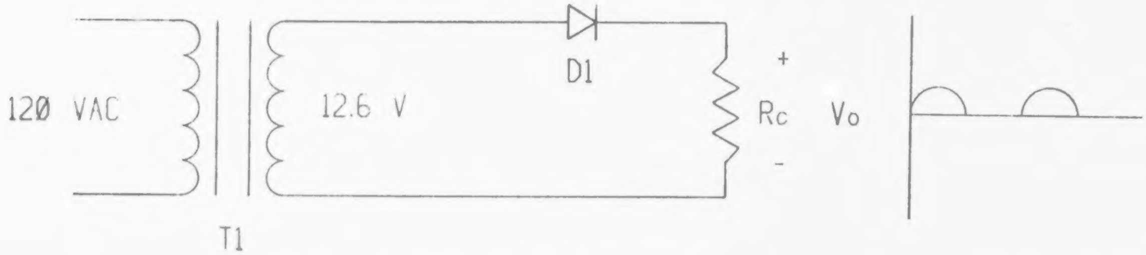


Figure D 3.1-2

Figure D 3.1-3 shown below illustrates a full-wave center-tapped rectifier circuit. This circuit uses two diodes, a center-tapped transformer, and a load. The transformer being center-tapped supplies 180 degrees out-of-phase current to the diodes. This enables each diode to conduct for exactly 180 degrees of each cycle. The resulting output voltage contains both halves of the waveform. Electrons flow through the load during the entire 360 degrees of the waveform. However, because the waveform voltage is not constant, this type of circuit has ripple and will also produce a buzzing in circuits. But because of the full-wave rectification, the frequency of the ripple is twice the frequency of the input voltage.

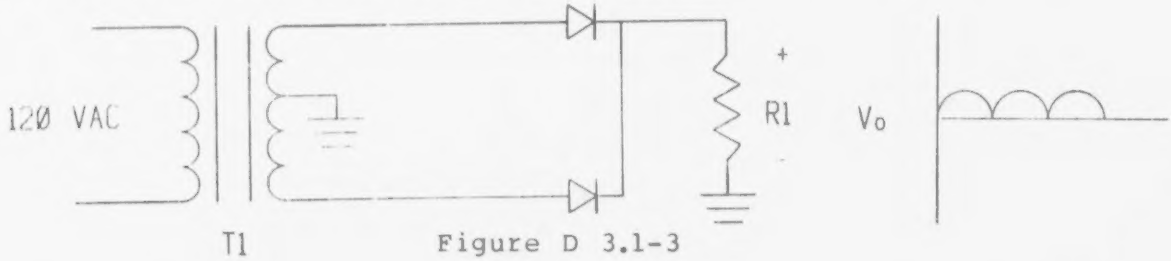


Figure D 3.1-3

INFORMATION SHEET D 3.1 CONT'D.

Figure D 3.1-4 below contains the schematic diagram and waveforms of a full-wave bridge rectifier. This circuit requires a total of four rectifier diodes, but does not need a center-tapped transformer. The transformer is connected to the bridge as shown. Notice that the connections are to the points where there are diodes pointing in each direction from the connection. The positive output is taken from the bridge at the point where the two cathodes are connected. The negative output is taken from the other point on the bridge where the two anodes are connected. This circuit produces twice the output voltage for a given input voltage as compared to a full-wave center-tapped rectifier circuit. The disadvantage is that the current must always flow through two diodes resulting in a 1.4 volt voltage drop.

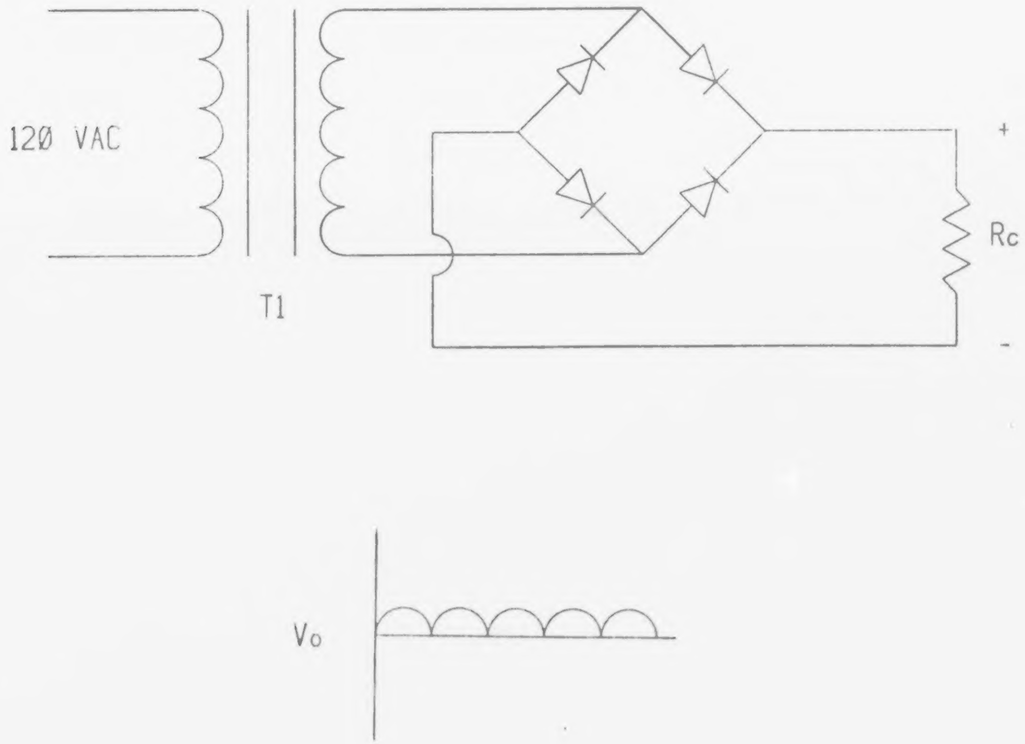


Figure D3.1-4

A common mode of failure for a rectifier is for one of the diodes to open circuit. If this happens to a half-wave rectifier, the output drops to zero volts. When it happens to a full-wave rectifier, the output decreases to that of a half-wave rectifier, and the ripple frequency decreases and the ripple voltage increases.

ACTIVITY SHEET

D 3.2

RECTIFIERS

1. Explain the operation of a half-wave rectifier.

2. Explain the operation of a full-wave center tapped rectifier.

3. Explain the operation of a full-wave bridge rectifier.

4. Explain the operation of a silicon rectifier diode.

5. Using a 25.2 volt center-tapped transformer, draw the schematic diagram for each of the above rectifiers. Draw the output waveform of each, label the peak output voltage and determine the average output voltage.

6. Which of the above rectifiers will require diodes with the greatest PIV? Explain.

INFORMATION SHEET

D 3.3

FILTERS

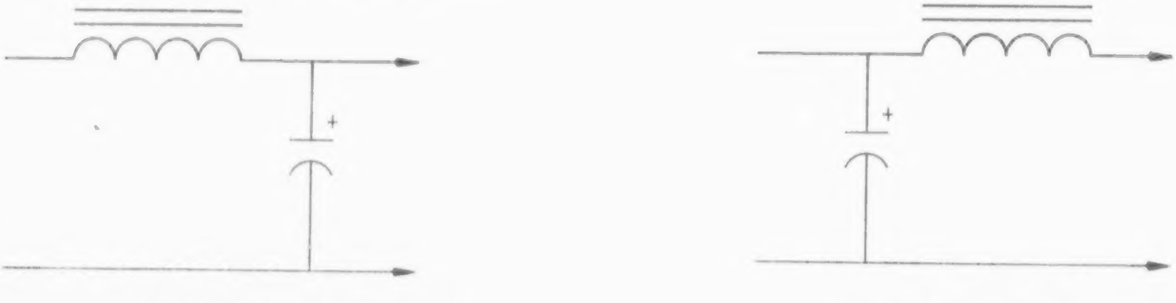
A rectifier should produce a flat constant DC output voltage, but it does not. The actual output of a rectifier is composed of both AC and DC components. The AC is superimposed on the DC voltage. The AC component is called the ripple of the rectifier. The amount of ripple in a rectifier can be determined as:

$$\text{ripple factor (in percent)} = \frac{\text{AC ripple voltage}}{\text{DC output voltage}} \times 100$$

The equivalent DC output voltage of a rectifier is equal to the average value of the voltage. The amplitude of the AC ripple voltage is the peak-to-peak value.

To reduce the ripple factor a capacitor is connected to the circuit as shown below. The larger the value of the capacitor, the smaller the ripple factor. If too large a capacitor is used, the rectifier diodes may be damaged by the surge current when the power supply is turned on. To prevent the diodes from being damaged, a small value resistor is often connected in series with the capacitor and the rectifier. This small value resistor, often less than one ohm, will protect the rectifier diodes without affecting the operation of the power supply.

There are two basic types of filters used on rectifiers: the capacitor input filter and the inductor input filter. These filters are shown in Figure D 3.3-1. The capacitor input filter provides a higher average output voltage because the capacitor is allowed to charge to peak voltage. In the inductor input, the inductor limits the surge current but keeps the capacitor from charging to peak voltage.



INDUCTOR INPUT

CAPACITOR INPUT

Figure D 3.3-1

A variation on the L-type filters is the π-filter shown below. This filter produces the best filtering action.

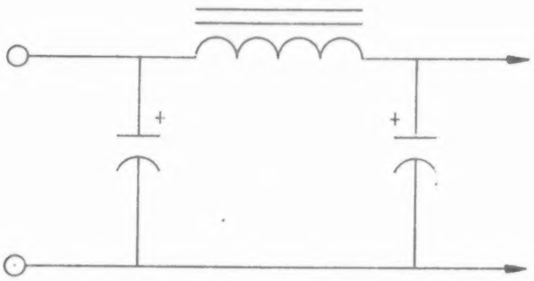


Figure D 3.3-2

As the operating voltage of circuits dropped from hundreds of volts required for vacuum tube operation to less than 25 volts used for most solid state devices, the filters changed. The voltage drop across the inductor became too large to accept, and at the same time technology developed larger electrolytic capacitors. Both of these events have reduced the filters on most power supplies to large value capacitors.

Figure D 3.3-3 is an enlarged view of the current and voltage waveform with the various parts of the waveform labeled.

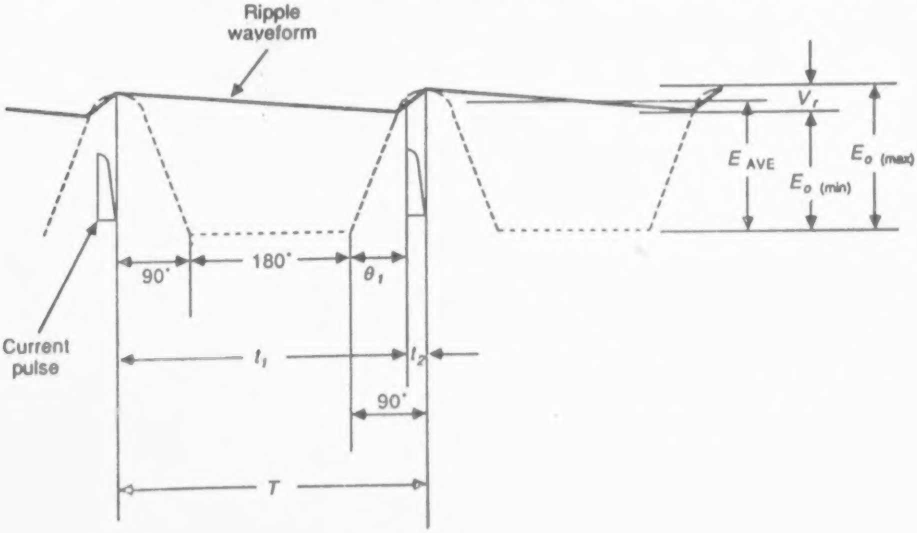


Figure D 3.3-3

Given the minimum and maximum output voltage and the frequency of the input waveform, the capacitance value can be calculated.

$E_{O(min)} = E_{O(max)} \sin\theta_1$

resulting in

$\sin\theta_1 = E_{O(min)}/E_{O(max)}$

and

t_1 = (time for 90^o) + (time for 180^o) + (time for $\theta_1{}^0$)

In that $Q = I_t$ and $C = Q/V$ it is possible to solve for the capacitance using $C = (I_L \times t_1)/V_r$

The actual charging time can then be found as

t_2 = (time for 90^o) - (time for $\theta_1{}^o$)

For example, let's assume that a rectifier circuit needed to supply 12VDC to a 120 ohm load, with a maximum of 8% of the average output voltage. The input frequency is 60Hz.

The ripple voltage, V_p would be 8% of 12V or

$$V_r = .08 \times 12$$
$$= .96V$$

$$V_{o(min} = 12 - .96$$
$$= 11.04V$$

$$V_{o(max)} = 12 + .96$$
$$= 12.96V$$

$$\theta_1 = \sin^{-1}(11.04/12.96)$$
$$= 58^o$$

T is the time for a complete cycle or 360^o and is 16.67ms. The time for 180^o would be

$$t_{100} = (180/360) \times 16.67$$
$$= 8.34ms$$

and for 90^o

$$t_{90} = (90/360) \times 16.67$$
$$= 4.17ms$$

and for θ_1 the time is

$$\theta_1 = (58/360 \times 16.67)$$
$$= 4.17\text{ms}$$

and for O_1 the time is

$$\theta_1 = (58/360) \times 16.67$$
$$= 2.69\text{ms}$$

Therefore t_1 is equal to the total time or

$$t_1 = (8.34 + 4.17 + 2.69)$$
$$= 15.2\text{ms}$$

The load current is found using Ohm's law.

$$I_L = E_o/R_L$$
$$= 12/120$$
$$= .1\text{A}$$

Using the equation for capacitance discussed above,

$$C = (I_L \times t_1)/V_r$$
$$= (1\text{A} \times 15.2\text{ms})/1.92$$
$$= 79{,}000\mu\text{F}$$

It is necessary to determine the actual diode current during the charging time of the capacitor to properly size the diode. The following equation determines the current flow. The times and load current are the same as these just discussed. The capacitor is discharging during both t_1 and t_2, but only charging during t_2.

$$I_{FM(rep)} = [I_L(t_1 + t_2)]/t_2$$

Notice in the schematic diagram for this power supply that there was a resistor, R_s in series with the diode. The purpose of R_s is to limit the initial current surge that occurs when the power supply is initially turned on. Because the capacitors are uncharged at the moment the power supply is turned on, they will act as a dead short across the power supply. According to Ohm's law, the only thing that will limit the flow of current in the circuit is the circuit's own resistance. This resistance may be a discrete resistor, or the resistance of the power supply wiring and the windings within the power supply's transformer. This limits the current to

$$I_{F(surge)} = V_P/R_5$$

From the data sheet of the diode it is possible to obtain its surge current rating, $I_{F(surge)}$. Using this it is possible to calculate the value of the surge resistor.

$$R_s = V_P/I_{FM(surge)}$$

Using this new information, let's determine the size of diode and surge resistor needed for the power supply above.

$t_2 = 4.13ms - 2.69ms$
$= 1.44$ ms

$I_{FM(rep)} = (.1A \times 16.67ms)/1.44ms$
$= 1.157$ A

The average forward diode current is 100mA and the peak repetitive forward current is 1.157A.

The maximum forward surge current taken from the diode's specification sheet is 35A. What must be the minimum amount of resistance in the above power supply circuit?

$R_s = V_P/I_{FM(surge)}$
$= 12.96/35$
$= .37$ ohms.

This amount may be found in the resistance of the circuit, and a resistor may be necessary. Measure the resistance of the transformer secondary to find out.

It is important to note that, if the power supply circuit is a full wave rectifier, each diode will conduct only one-half of the average current. But it is also important to remember that the surge current is **not** reduced.

Figure D 3.3-4 presents the outputs of a normal rectifier and rectifiers with a leaky filter capacitor, an open filter capacitor, and an open rectifier diode for open secondary in a full-wave rectifier.

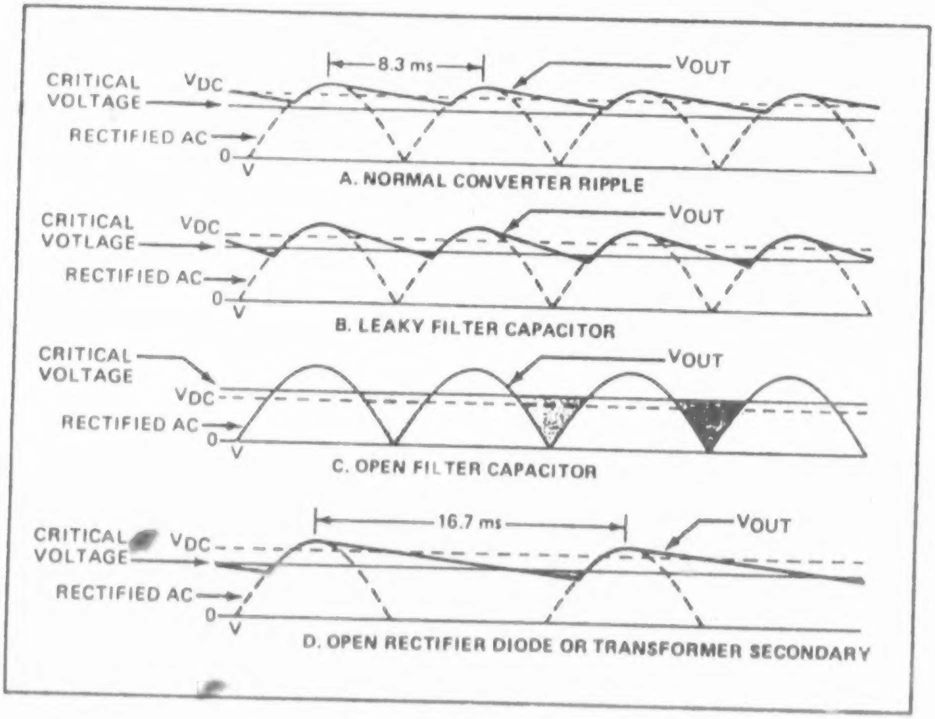


Figure D 3.3-4

ACTIVITY SHEET

D 3.4

FILTERS

1. Explain the function of a surge resistor.
2. Define ripple factor, bleeder resistor, ripple, inductor, and regulation as they relate to power supplies.
3. What is the ripple frequency of a full-wave rectifier?
4. What is the ripple frequency of a half-wave rectifier?
5. What effect does load resistance have on the ripple factor of a power supply?
6. What effect will an open-filter capacitor have on the output voltage, both AC and DC of a power supply? Explain.
7. What effect will a shorted-filter capacitor have on the output voltage, both AC and DC, of a power supply? Explain.
8. Which type of filter produces the highest output voltage? Explain.
9. Which type of filter does not need a surge resistor? Explain.
10. Why is the inductor not used in most low-voltage, high-current power supplies?

ACTIVITY SHEET D 3.4

ANSWER SHEET

1. Prevent damage to rectifier(s).

2. See text.

3. Twice the input frequency.

4. The same as the input frequency.

5. The greater the load, the greater the ripple.

6. Will get a large ripple and a lowered DC or average voltage.

7. Will take out fuse, rectifier, and/or transformer--all outputs zero.

8. Capacitor input--charges to peak voltage.

9. Inductive input filter--inductive reactance limits surge current.

10. Inductor becomes too large and expensive.

PROGRAM: ELECTRONICS

TASK: POWER SUPPLIES

TASK #: D 3.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

USING A SCHEMATIC, ANALYZE, CONSTRUCT AND TROUBLESHOOT POWER SUPPLIES.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 5 out of 6 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 5 out of 6 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

POWER SUPPLIES

D 3.5

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the required equipment used?	Y N
*2.	Was the required data recorded?	Y N
3.	Was the equipment used according to specifications?	Y N
*4.	Were all safety precautions followed?	Y N
5.	Was equipment returned to the proper storage area?	Y N
*6.	Was the experiment summarized properly?	Y N

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

POWER SUPPLIES

EXAM

D 3.6

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Power Supplies. Each of the statements is true or false. Place the correct answer (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 12 out of 15 items correctly, 80%.

POWER SUPPLIES

EXAM

D 3.6

1. The larger the PIV of a diode, the larger its forward voltage drop.

   A. True
   B. False

2. The average DC output voltage of a FWB rectifier will be approximately twice the output voltage of a half-wave rectifier using the same power transformer.

   A. True
   B. False

3. The ripple frequency of a FWB rectifier is 60 Hz.

   A. True
   B. False

4. The ripple frequency of a half-wave rectifier is 60 Hz.

   A. True
   B. False

5. The no-load voltage across a filter capacitor will be equal to the peak output voltage of the transformer minus the rectifier voltage drop(s).

   A. True
   B. False

6. The greater the load requirements on a power supply, the greater its ripple voltage.

   A. True
   B. False

7. A shorted filter capacitor on a power supply will cause an increase in the ripple voltage of the power supply.

   A. True
   B. False

8. An FWB rectifier power supply with an open rectifier diode in the bridge will have no output voltage.

   A. True
   B. False

9. A surge resistor in a power supply performs the same function as a bleeder resistor.

   A. True
   B. False

10. You can safely replace a 1000mfd 100Vdc capacitor with a 10000mfd 200Vdc capacitor in a power supply.

    A. True
    B. False

11. A capacitor input filter may require a surge resistor to protect the rectifier diodes.

    A. True
    B. False

12. Full-wave bridge rectifiers may be obtained as an integrated circuit.

    A. True
    B. False

13. Another name for a capacitor filter is a choke.

    A. True
    B. False

14. The smaller the percent of a regulation in a power supply, the more stable the output voltage.

    A. True
    B. False

15. A short between the frame and primary side of a transformer will cause the output voltage to increase.

    A. True
    B. False

EXAM D 3.6

ANSWER KEY

1. B
2. A
3. B
4. A
5. A
6. A
7. B
8. B
9. B
10. A
11. A
12. A
13. B
14. A
15. B

INFORMATION SHEET

D 3.7

REGULATORS

The widespread use of integrated circuits and microprocessor based equipment has created a demand for simple, dependable, and accurate voltage regulators. The function of a voltage regulator is to refine the filtering process. Voltage regulators maintain the output voltage at a precise level and reduce ripple to near zero volts.

The voltage regulation of a power supply can be expressed as a percentage. The smaller the percentage of regulation, the better the regulator. Regulation can be found by applying the formula below.

$$\text{percent regulation} = \frac{\text{No load E} - \text{full load E}}{\text{full load E}} \times 100$$

For a voltage that changes between 11 and 12 volts, the percent of regulation is:

$$\text{percent regulation} = \frac{12 - 11}{11} \times 100 = 9.1\%$$

There are two types of electronic voltage regulator: shunt and series. Figure D 3.7-1 represents a shunt voltage regulator. The regulator is connected in parallel with the load resistance. If the voltage attempts to increase across the load it must also increase across the regulator. The regulator senses this and lowers its resistance causing more voltage to be dropped across the series resistance. This prevents the voltage from increasing across the load. The opposite happens when the load voltage tries to decrease. The regulating action of a shunt regulator is as a variable resistance in parallel with the load. The disadvantage with this type of regulator is that it dissipates all the power when there is no load.

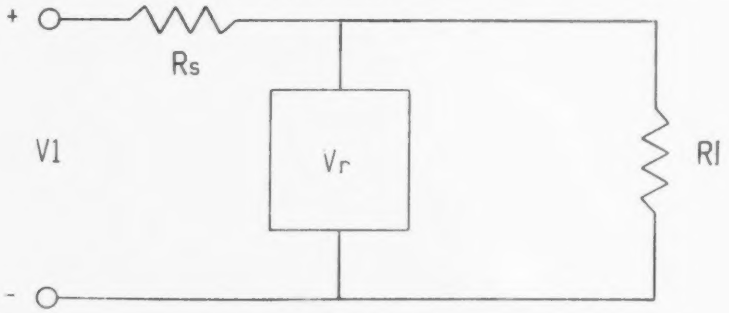


Figure D 3.7-1

In Figure D 3.7-2 the regulator circuit is in series with the load. As the resistance of the load changes, the resistance of the regulator will change an equal amount in the opposite direction keeping the total overall resistance seen by the power supply constant. This keeps the power supply voltage constant. In both the series and shunt regulator the regulator will also respond to changes in the circuit caused by variations in the power source.

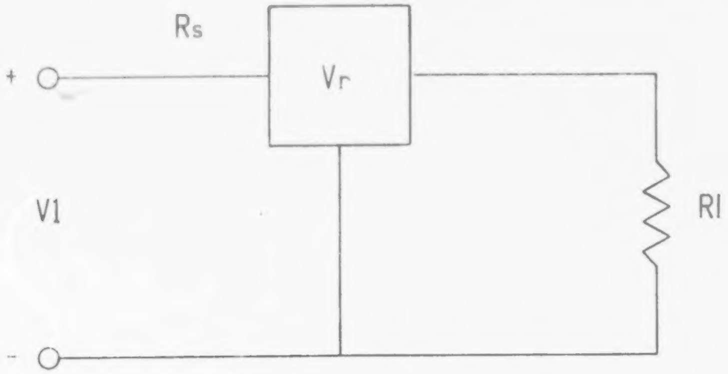
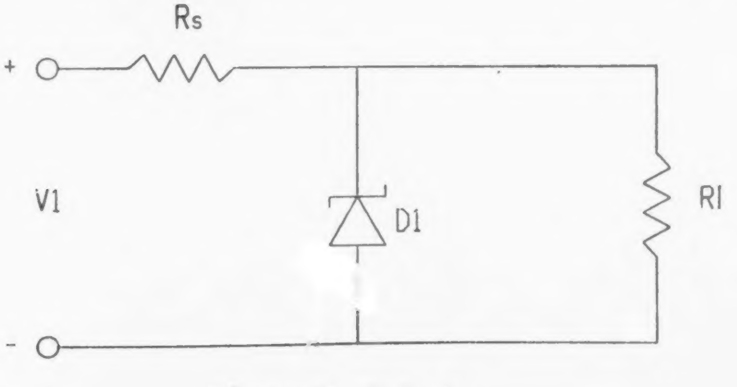


Figure D 3.7-2

Figure D 3.7-3 is the schematic diagram of a simple shunt regulator consisting of a series dropping resistor, and a zener diode. Resistor R_s is the series dropping resistor. This resistor is in series with the zener diode. The zener diode is the active element or actual regulator in this circuit. The zener diode will conduct as long as the voltage applied across it is greater than its zener voltage rating. It will change its internal resistance to maintain this constant zener voltage across itself. If the input voltage drops below the zener voltage, the regulator will lose its ability to regulate. The zener diode cannot create voltage. Should the current flow become excessive because of too much power supply voltage, the zener diode will destroy itself in an attempt to regulate the voltage.



FigureD 3.7-3

The following equation can be used to design a simple shunt regulator. The value of R_s is determined by:

$$R_s = \frac{V_{in(min)} - V_Z}{1.1\ I_{L(max)}}.$$

To insure that the zener diode does not come out of conduction, you must always take the smaller value for the series resistor, if you are using standard value resistors, when your calculations fall between two values.

The power dissipation requirements of the zener can be determined as:

$$P_{Z(max)} = V_Z \frac{V_{in(max)} - V_Z}{R_s} - I_{L(min)}.$$

Using the power formula, the wattage size for the resistor is:

$$P_{RS} = \frac{(V_{in(max)} - V_Z)^2}{R_S}.$$

Figure D 3.7-4 illustrates the schematic diagram of a series regulator. Here a transistor is used in the emitter follower (common collector) configuration as a variable resistance. The zener diode is a simple shunt regulator that maintains a regulated voltage at the base of the transistor. The transistor is capable of regulating a current equal to the zener current times the gain of the transistor, provided this does not exceed the power capability of the transistor. In this circuit, a light load current causes the transistor to dissipate very little power. A large load requires the regulator to dissipate more power. Also, the greater the difference between the unregulated voltage and the regulated voltage, the greater the power dissipation in the transistor.

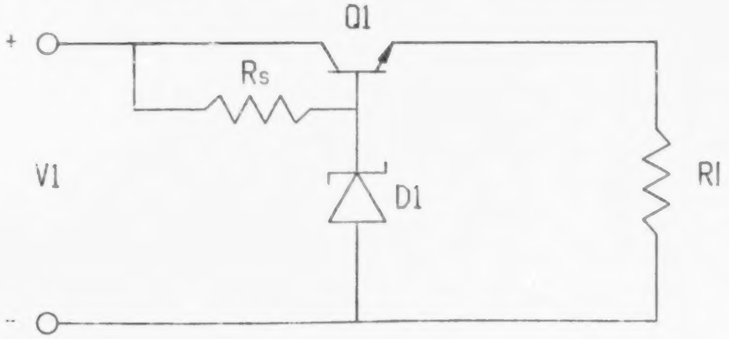


Figure D 3.7-4

The output voltage of this type of a regulator is:

$$V_{out} = V_{zener} - V_{BE}.$$

The maximum amount of regulated output current can be:

$$I_{out} = .9\ I_{zener} \times \text{Beta}.$$

Typical failure for a shunt regulator is for the zener diode to fail. If the diode shorts, the output voltage goes to zero. If the diode opens, the output voltage will equal the rectifier voltage minus the voltage dropped across the series resistance.

Failure in series regulators almost always involves the series pass transistor. Excessive current, heat, and voltage are usually the cause. When the transistor fails, it usually will short supply, full supply voltage to the load.

As good as these regulators are, they were improved upon by the development of the **monolithic** integrated circuit voltage regulator. The entire circuitry of a voltage regulator is formed on a single silicon chip. These integrated circuits are capable of regulating power sources from just a few volts and milliamperes to hundreds of volts and amperes. The regulation is usually accurate to within +/-5%. They are short circuit proof and over temperature protected. The cost of a low current (under 2 amperes) regulator is around two dollars.

The schematic diagram below in Figure D 3.7-5 shows the typical application of a voltage regulator. The rectified and filtered DC voltage is supplied to the input lead. The common lead is connected to the common or ground lead between the power supply and the load. The output from the regulator is connected to the load. The input voltage must always be at least 2 volts greater than the desired output voltage or the regulator will not be able to regulate. A supply voltage in excess of the maximum specified by the data sheet will destroy the regulator. To get the maximum current rating from the device it is necessary to fasten it to a proper **heat sink**.

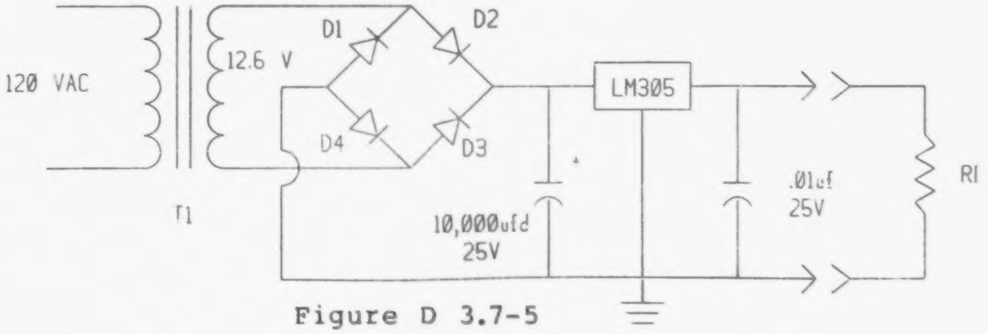


Figure D 3.7-5

It is possible to construct high voltage regulators by connecting the reference or ground lead of a regulator to a zener diode instead of directly to ground. The output voltage of the regulator is equal to the sum of the zener voltage and the regulator voltage. As stated earlier, extreme caution must be exercised to prevent excessive voltage from being applied to the voltage regulator. Additional current capabilities are possible by operating two or more regulators in parallel. A voltage regulator may be used in place of a zener diode to provide the regulation voltage to the base of a series pass transistor for very high current applications.

Troubleshooting power supplies is most easily accomplished if done in a systematic and logical way. Figure D 3.7-6 illustrates the four basic sections of a typical AC to DC power supply.

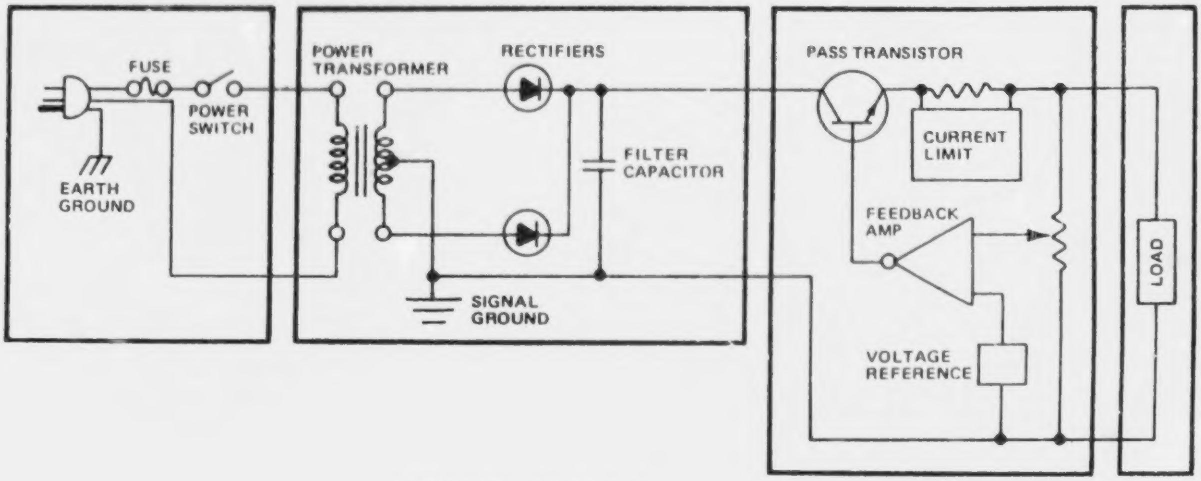


Figure D 3.7-6

The first step is to do a visual inspection on each of the sections, starting with the input. Many problems are caused by faulty switches, loose connections or open fuses. Burn marks on the transformer or around the diodes indicate arcing and/or excessive temperature. A ruptured seal on an electrolytic capacitor indicates that the capacitor has failed. In the regulator section parts should look "normal." Check for signs of excessive temperature around the series pass transistor or IC regulator which is often the result of blocked air vents. The load is often a necessary part of the power supply circuit and, if removed, it will cause the power supply to operate improperly or not at all.

If there are no visual indications of failure, make sure that the circuit is deenergized, and repeat the checks using an ohmmeter or continuity checker. You should know how to properly test switches, fuses, diodes, and transformers for proper operation. It is not possible with a standard ohmmeter to discover single shorted turns in a transformer. This requires a special low range ohmmeter.

If the ohmmeter tests fail to locate a fault, it will be necessary to carefully apply power to the power supply and follow the flow of electricity through the circuit with the aid of a schematic diagram. Most of the measurements may be made with a voltmeter; but, when checking for excessive ripple, it will be necessary to use an oscilloscope.

ACTIVITY SHEET

D 3.8

REGULATORS

1. Explain the operation of a voltage regulator.
2. Explain the operation of a current regulator.
3. State the advantages and disadvantages of regulator integrated circuits.
4. Which type of regulator dissipates the most power when there is no load connected to its output, a shunt or a series? Explain.
5. When a short is applied across the output of a shunt regulator, which component within the regulator is most likely to fail? Why?
6. When a short is applied across the output of a series regulator, which component within the regulator is not likely to fail? Why?
7. Is it necessary to use filter capacitors on a rectifier when using a voltage regulator? Explain.

Figure D 3.8-1 is used for problems 8 and 9.

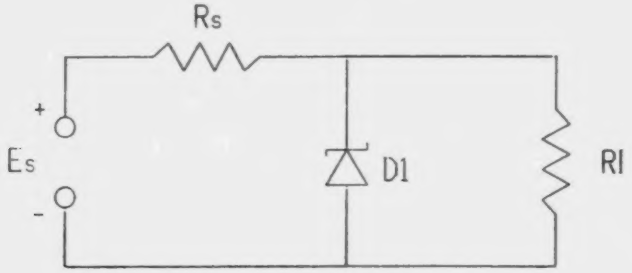


Figure D 3.8-1

8. Solve the following for the values indicated.

GIVEN: V_Z = 18 V, R_S = 33 ohms, R_L = 180 ohms, and E_S = 30 V

FIND: V_O = I_S = I_L = I_Z =

9. Using Figure D 3.8-2 above, and a V_Z of 12 V with an R_S of 47 ohms, the input voltage has 2Vp-p ripple, and a load that can vary in resistance from 100 ohms to infinity. Solve for the following.

FIND: $I_{S(max)}$ = $I_{S(min)}$ =

$I_{Z(max)}$ = $I_{Z(min)}$ =

P_Z =

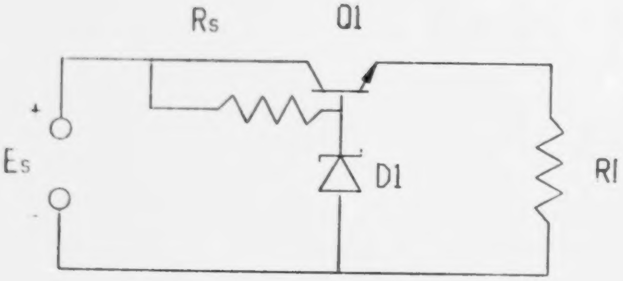


Figure D 3.8-2

10. Using Figure D 3.8-2, assume that E_s = 18 V, V_Z = 12.7 V, R_s = 500 ohms, Beta of the transistor is 100, R_L is 80 ohms, and the transistor is silicon. Solve for the following, where P_Q is the power dissipated in the series pass transistor.

FIND: V_O = I_L = P_Q =

ACTIVITY SHEET D 3.8

ANSWER SHEET

1. See Text.

2. See Text.

3. See Text.

4. The shunt regulator must pass all current to maintain voltage regulation.

5. Rectifier(s): the regulator dissipates no power when the output is shorted.

6. The series pass transistor must handle all of the current flow while dissipating all the voltage.

7. Yes, to prevent the unregulated voltage from dropping below the minimum necessary to insure regulation.

   See problem.

8. GIVEN: $V_Z = 18$ V, $R_S = 33$ ohms, $R_L = 180$ ohms, and $E_S = 30$ V

   FIND: $V_O = 18\text{VDC}$ $I_S = 364\text{mA}$ $I_L = 100\text{mA}$ $I_Z = 264\text{mA}$

9. FIND: $I_{S(max)} = 383\text{mA}$ $I_{S(min)} = 382\text{mA}$

   $I_{Z(max)} = 383\text{mA}$ $I_{Z(min)} = 262\text{mA}$

   $P_Z = 4.6\text{W}$ -- 5W required

   See problem.

10. FIND:

    $V_O = 12\text{V}$

    $I_L = 150\text{mA}$

    $P_Q = .9\text{W}$

PERFORMANCE/PRODUCT CHECKLIST

D 3.9

REGULATORS

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the required equipment used?	Y N
*2.	Was the required data recorded?	Y N
3.	Was the equipment used according to specifications?	Y N
*4.	Were all safety precautions followed?	Y N
5.	Was equipment returned to the proper storage area?	Y N
*6.	Was the experiment summarized properly?	Y N

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

REGULATORS

CRITERION

D 3.10

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Regulators. Place the correct answer (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 13 out of 15 items correctly, 80%.

EXAM D 3.10 CONT'D.

1. Integrated circuit voltage regulators are available as fixed voltage regulators only.

   A. True
   B. False

2. Integrated circuit voltage regulators will be damaged/destroyed by shorting the output of the regulator to ground.

   A. True
   B. False

3. A common mode of failure for a series voltage regulator is for the series pass transistor to short collector to emitter.

   A. True
   B. False

4. The greater the difference between the unregulated voltage and the desired regulated voltage, the greater the power dissipation in the regulator.

   A. True
   B. False

5. The greater the load current in a shunt voltage regulator, the less the current flow in the regulating element.

   A. True
   B. False

6. If the output from a filtered rectifier increases in a shunt regulator, the current flow through the series resistor will decrease.

   A. True
   B. False

7. If the load is disconnected from a shunt regulator, the current through the regulating element decreases to zero.

   A. True
   B. False

8. A series voltage regulator will dissipate maximum power when sending maximum current into a load of zero resistance.

   A. True
   B. False

9. Power FEAs cannot be used as series pass transistors in voltage regulators.

   A. True
   B. False

10. An integrated circuit voltage regulator can be connected to function correctly as a current regulator.

   A. True
   B. False

Figure D 3.10-1 is used for problems 11 and 12.

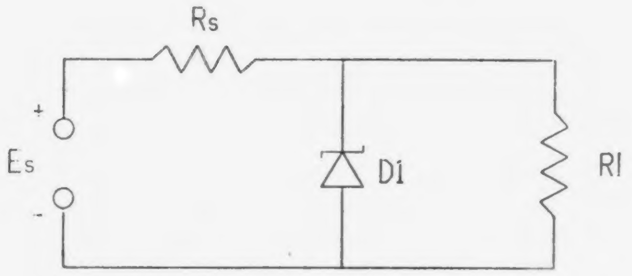


Figure D 3.10-1

11. GIVEN: $V_Z = 18$ V, $R_S = 33$ ohms, $R_L = 180$ ohms, and $E_5 = 30$ V,

FIND: $V_O =$ $I_S =$ $I_L =$ $I_Z =$

12. Given a V_Z of 12 V with an R_S of 47 ohms, the input voltage has 2Vp-p ripple, and a load that can vary in resistance from 100 ohms to infinity,

FIND: $I_{S(max)} =$ $I_{S(min)} =$

$I_{Z(max)} =$ $I_{Z(min)} =$

P_Z

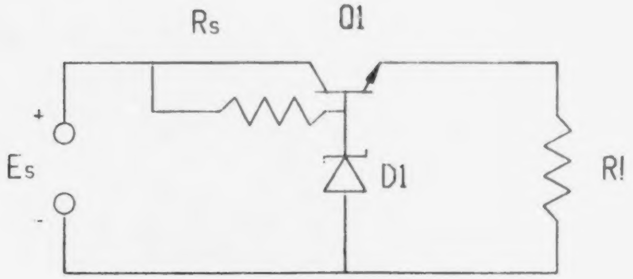


Figure D 3.10-2

13. Using Figure D 3.10-2 above, assume that E_S = 18 V, V_Z = 12.7 V, R_S = 500 ohms, Beta of the transistor is 100, R_L is 80 ohms, and the transistor is silicon. Solve for the following, where P_Q is the power dissipated in the series pass transistor.

FIND: V_O = I_L = P_Q =

Use Figure D 3.10-3 below to answer questions 14 and 15.

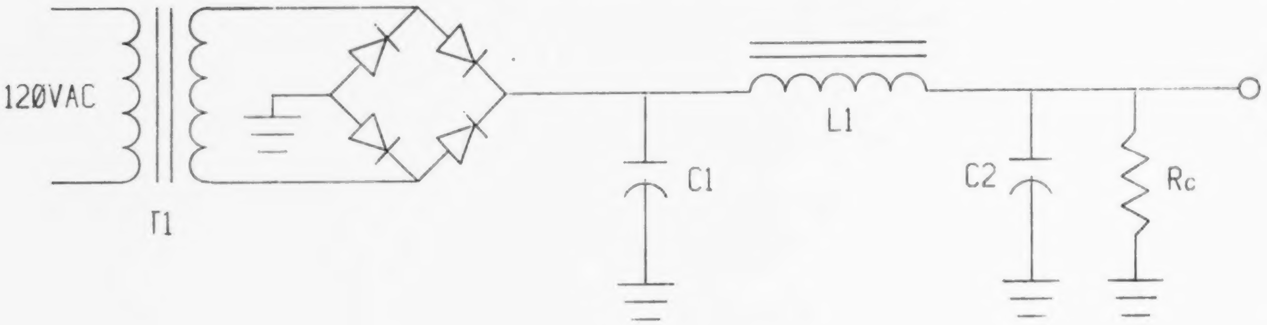


Figure D 3.10-3

14. The output voltage has excessive ripple. The most likely cause is __________.

a. A_1 secondary open
b. L_1 open
c. C_2 shorted
d. C_2 open

15. There is no DC output voltage. The most likely cause is ______________.

a. D_1 open
b. L_1 open
c. C_1 open
d. C_2 open

EXAM D 3.10

ANSWER KEY

1. B
2. B
3. A
4. A
5. A
6. B
7. B
8. A
9. A
10. A
11. V_O = 18V I_S = 364 ma I_L = 100 ma I_Z = 264 ma
12. $I_{S(max)}$ = 426 ma $I_{S(min)}$ = 340 ma $I_{Z(max)}$ = 306 ma
    $I_{Z(min)}$ = 220 ma P_Z = 5.112 W
13. V_O = 12V I_L = 159 ma P_Q = .843 W
14. D
15. B

ELECTRONICS

ANALYZING ANALOG CIRCUITS

D 4: DIFFERENTIAL OPERATIONAL AMPLIFIERS

TASK:	Using a schematic, analyze, construct and troubleshoot differential operational amplifiers.
PURPOSE:	A very popular device used in many types of electronic instruments is the operational amplifier. This is a linear integrated circuit capable of large voltage and power gains. This learning guide will explain the terms and processes necessary to assist in the understanding of this popular device.
OBJECTIVE:	Given a written exam you will analyze operational amplifiers.

ESTIMATED CLASS TIME: 10 HOURS

DIFFERENTIAL OPERATIONAL AMPLIFIERS

LEARNING STEPS

D 4

READ: Information Sheet D 4.1, "Differential Operational Amplifiers."

READ: Information on differential operational amplifiers from the following resource list.

COMPLETE: Activity Sheet D 4.2, "Differential Operational Amplifiers."

REVIEW: Information Sheet D 4.1, and Activity Sheet D 4.2.

COMPLETE: Laboratory performance on differential operational amplifiers. Contact your instructor.

COMPLETE: Performance Checklist D 4.3.

COMPLETE: Written Exam D 4.4 for mastery of this task.

DIFFERENTIAL OPERATIONAL AMPLIFIERS

RESOURCES

D 4

1. ELECTRONIC PRINCIPLES, 3rd Edition, by Malvino (McGraw-Hill, 1984).
2. ELECTRONIC TROUBLSHOOTING, by Oleksy (Bobbs-Merrill, 1983).
3. ELECTRONICS IN INDUSTRY, 5th Edition, by Chute & Chute (McGraw-Hill, 1979).
4. ESSENTIALS OF SOLID STATE ELECTRONICS, by Faber (Wiley, 1985).
5. SEMICONDUCTOR TECHNOLOGY, by Weedon (Energy Concepts, Inc., 1985).
6. SOLID-STATE ELECTRONICS, 2nd Edition, by Rutkowski (Bobbs-Merrill, 1983).
7. Any appropriate electronics textbook

REQUIRED EQUIPMENT

0 - 25 VDC @ 1A Power Supply
0 - 40 VAC @ 1A Isolated Power Supply
0 - 1IMHZ Function Generator
10 MHZ Dual Trace Oscilloscope
Digital Multimeter

INFORMATION SHEET

D 4.1

DIFFERENTIAL OPERATIONAL AMPLIFIER

Amplifiers can be used to perform mathematical operations such as addition, subtraction, integration, and differentiation. These amplifiers became known as **operational amplifiers.** Modern operational amplifiers (op-amps) are linear integrated circuits (as opposed to digital integrated circuits). These IC's use low voltage power supplies, are reliable, very inexpensive, and easy to design. The schematic symbol for an op-amp is shown in Figure D 4.1-1. An operational amplifier has two input terminals, the noninverting (+) and the inverting (-), and one output terminal.

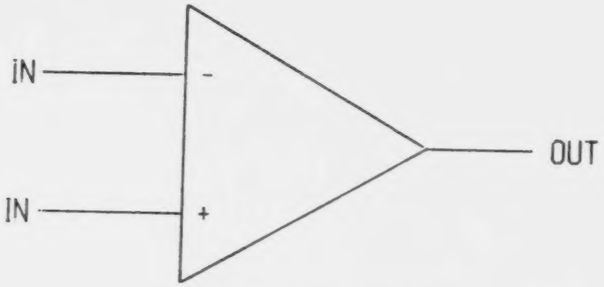


Figure D 4.1-1

The operational amplifier has a differential input. Figure D 4.1-2 below shows the schematic diagram of a typical differential amplifier. The circuit has two inputs and the output waveform is actually the difference of the input signals as reflected in the waveforms of each collector. Thus the amplifier is called a differential amplifier.

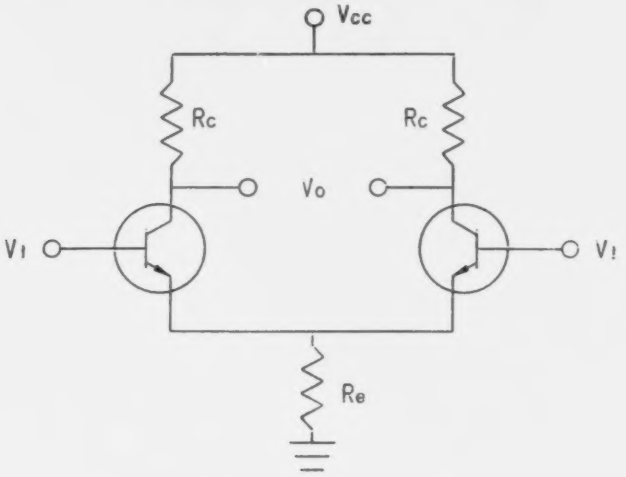
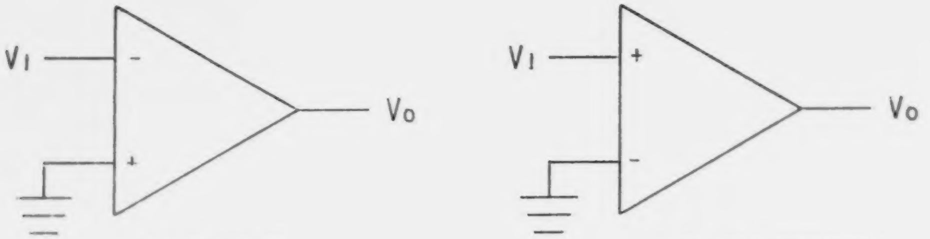


Figure D 4.1-2

When the components used to construct each half of the differential amplifier are electrically identical, and the same signal is applied to both inputs, the signal produced by each collector is identical, and there is no difference in the collector waveforms. Because both collector voltages are changing at the same time and there is no relative difference between them, there is no output voltage. The ability of the circuit to not eliminate identical signals that appear at both inputs is known as common mode rejection. This capability is used when one input is connected to one lead in a cable, and the other side connected to the other lead. Any electrical noise that is common to the two wires will be eliminated by passing the signal through the differential amplifier. The cable is often constructed as a twisted pair insuring that any electrical noise appears equally on each lead.

There are applications where the differential amplifier is operated in the single-ended mode. One of the amplifier's inputs is held at ground, and a signal is applied to the other input. The output will either be in phase with the input signal, or 180° out of phase with the input signal. The in phase input is known as the noninverting input and the out-of-phase input is known as the inverting input. Figure D 4.1-3 is the symbol for an operational amplifier with differential inputs. The noninverting input is identified by the + symbol and the inverting input is identified by the - symbol.



INVERTING

NON-INVERTING

Figure D 4.1-3

An ideal operational amplifier should have infinite voltage gain, infinite bandwidth, infinite input impedance, and zero output impedance. Actual operational amplifiers approach the ideal characteristics. Current op-amps are capable of large gains, have very high input impedance, have low output impedance, and are very inexpensive. These characteristics make it is easy to design circuits using operational amplifiers. One drawback is that many operational amplifiers require two power supplies for proper operation.

The gain of any amplifier is the ratio of its input signal to its output signal. For example the voltage gain of an amplifier is determined by V_{out} / V_{in}. Current and power gains may be determined using similar formulas. Amplifiers and especially operational amplifiers can produce large amounts of gain. A method of measuring the gain of amplifiers has been developed. The unit of measure is the **Bel**. A smaller form of the Bel is the decibel. The decibel is the ratio of one power to another or one voltage to another. The power gain expressed in decibels (dB) is:

$$A_p(dB) = 10 \log(P_{out}/P_{in})$$

which can be determined from the voltage/resistance ratio:

$$A_p(dB) = 10 \log((V^2out/R_{out})/(V^2out/R_{out}))$$

Then where $R_{out} = R_{in}$ then the equation becomes:

$$A_p(dB) = 10 \log(V^2out/V^2in)$$

This is reduced to:

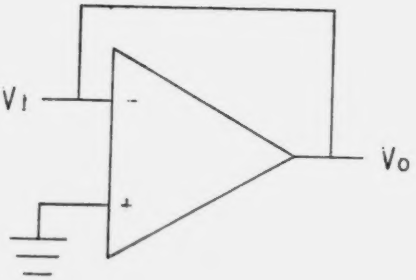
$$A_v(dB) = 20 \log(V_{out}/V_{in})$$

When the dB ratio is greater than one, the gain of the amplifier is positive. If the ratio is less than one, the gain is negative.

It is often convenient to assign a certain value of gain as the 0 dB reference. This represents the expected gain of the amplifier. As the gain of the amplifier increases or decreases from this value, the difference is expressed in dB's.

For example, an amplifier has an output voltage of 6 volts with an input frequency of 5 kHz. The input signal is held at a constant voltage while the input frequency changes from 100 Hz to 20 kHz. The output voltage of the amplifier is measured. Assume that the output readings ranged from a low of about 4 volts at 100 Hz to a high of 12 volts at 5 kHzG. The frequency response and output voltage of the amplifier would be stated as 100 Hz to 10 kHz, +6dB, -3dB.

The frequency response of an op-amp is determined by the internal construction of the op-amp. The maximum rate of change of the output voltage in response to the application of a step input voltage is the slew rate of the operational amplifier. Figure D 4.1-4 shows the amplifier configuration used to measure this parameter. The op-amp must be connected as a unity-gain, noninverting configuration, which will be discussed later. This configuration produces the worst-case (slowest) slew rate.



FigureD 4.1-4

A fixed amount of time is required for the output voltage to move from its lower limit $-V_{(max)}$ to its upper limit $+V_{(max)}$ after the step input is applied. The slew rate is calculated using this information,

$$\text{Slew rate} = V_{out} / t$$

where V_{out} is equal to $+V_{(max)} - (-V_{(max)})$ and t is the time for the output voltage to go from $-V_{(max)}$ to $+V_{(max)}$. The slew rate of an op-amp is expressed in volts per microsecond (V/µs).

The maximum output signal voltage of an op-amp is often thousands of times larger than the input voltage. The maximum gain of an op-amp is specified by manufacturers as the **open-loop gain** of the amplifier, A_{vol}. Open-loop gain is defined as the ratio of an operational amplifier's output voltage to its input voltage. The term open loop gain implies that there is no feedback loop between the output of the amplifier and its input.

INFORMATION SHEET D 4.1 CONT'D.

Figure D 4.1-5 shows the typical open-loop voltage gain for a 741 operational amplifier. The gain of the operational amplifier decreases as the frequency of the input signal increases. The amplifier has its maximum gain of 100,000 below 10 Hz. This decreases to unity gain at 1 MHz. From the curve, the maximum frequency that the device can amplify before the gain drops to the **half-power point** is about 20 Hz. The maximum range of frequencies capable of being amplified without excessive loss is the bandwidth of the amplifier. The bandwidth of the amplifier can be calculated using the following equation:

$$\text{Bandwidth} = f_{max} - f_{min}$$

F_{max} is the **upper cutoff frequency,** and f_{min} is the **lower cutoff frequency.** Looking at the figure it is possible to increase the bandwidth of the amplifier by simply reducing the gain of the amplifier. If the amplifier were to operate at a gain of only 25dB, the bandwidth becomes 120,000 Hz.

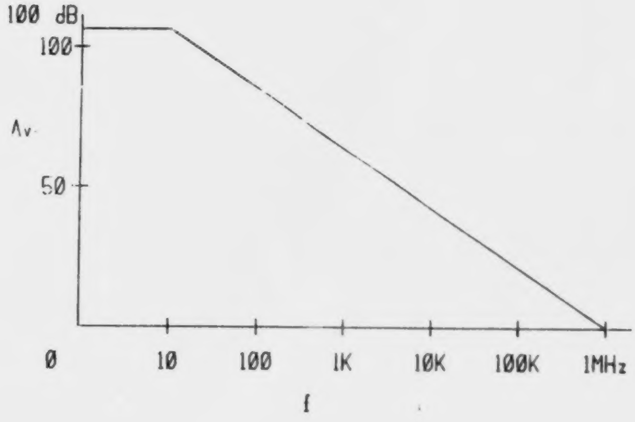


Figure D 4.1-5

The range of frequencies (bandwidth) that the amplifier can amplify without excessive loss becomes dc to over 100,000 Hz when the gain of the amplifier is reduced to 25 dB. The product of the gain and the bandwidth always produces the same result. With the 741 this is 1 X 10^6. This resulting number is called the bandwidth product and is used in the design of amplifier circuits.

Figure D 4.1-6 is the schematic diagram of an inverting amplifier. In an inverting amplifier the output waveform is 180 out-of-phase with the input waveform. Connecting the out-of-phase waveform back to the input of the operational amplifier through a resistance subtracts from the input. This feedback cancels part of the input, reducing the output of the amplifier. This type of feedback is called negative feedback since it reduces the input signal. If connected without resistance, negative feedback will reduce the gain of the amplifier to one.

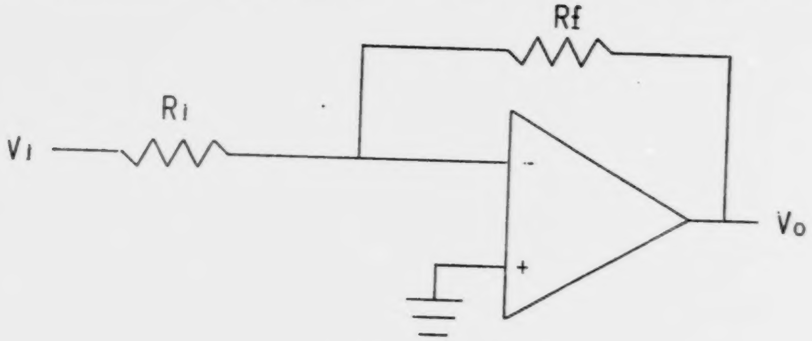


Figure D 4.1-6

The other form of feedback is called positive feedback. Positive feedback occurs when the feedback is in phase with the input signal. If this form of feedback is left uncontrolled, the output will increase without bounds.

Using Ohm's law and Kirchoff's laws the gain of the circuit shown above is determined as:

$$A_v = V_o / V_1 = R_F / R_i$$

If the feedback resistance, R_F, equals 10k ohms, and the input resistor, R_i, equals 1000 ohms, the gain of the amplifier will be:

$$A_v = 10000 / 1000 = 10$$

The inverting input of the amplifier is at virtual ground. No signal current flows into the input of an op-amp. All the input voltage is dropped across the resistor R_i while all the feedback voltage is dropped across resistor R_F. Because these voltages are equal when the amplifier gain is stable, there is no voltage at this point.

INFORMATION SHEET D 4.1 CONT'D.

The schematic diagram of a noninverting amplifier is shown in Figure D 4.1-7. A noninverting amplifier has an output that is in phase with its input signal. Non-inverting amplifiers use negative feedback to control their gain also. The resistor R_s is used to balance the input to the op-amp against any small input bias current. It has no effect on the gain of the circuit.

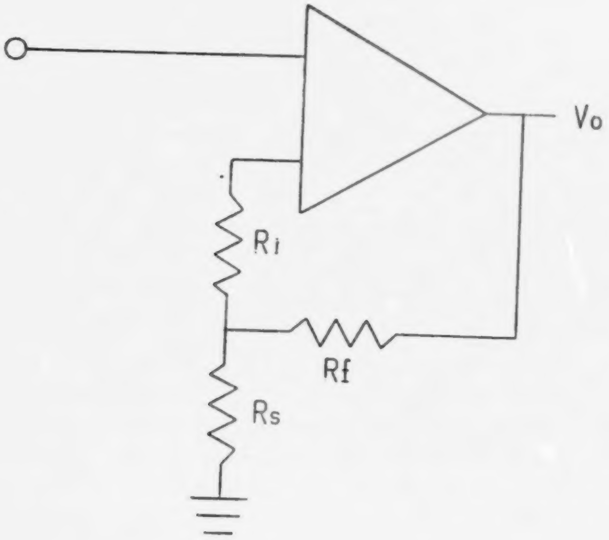


Figure D 4.1-7

The gain of a noninverting amplifier is calculated as:

$A_v = (R_F + R_1) / R_1$

Noninverting amplifiers will always have a gain greater than one.

ACTIVITY SHEET

D 4.2

DIFFERENTIAL OPERATIONAL AMPLIFIER

1. Explain the operation of a differential operational amplifier.

2. Define open loop gain as it relates to operational amplifiers.

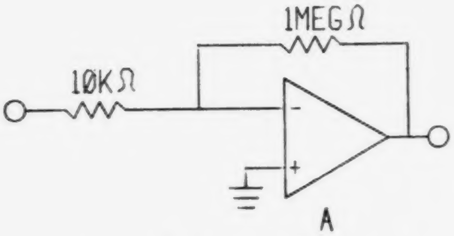
3. Define gain-product bandwidth, common-mode rejection ratio, offset current, offset voltage, input voltage range, inverting input, non-inverting input, open loop gain and slew rate.

4. Explain how to calculate the gain of an inverting amplifier.

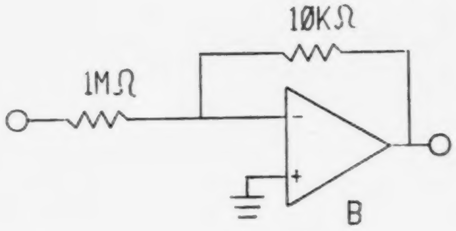
5. Explain how to calculate the gain of a noninverting amplifier.

6. List the parameters available from a data sheet.

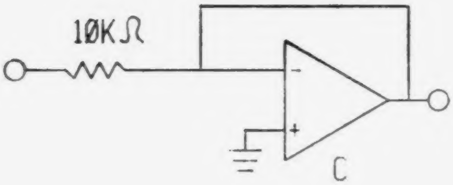
7. Indicate the circuit configuration, gain, and input impedance of each of the following operational amplifier circuits.



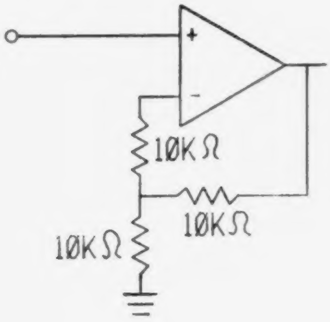
______ A_e= ____ Z_i= ____



______ A_e= ____ Z_i= ____



______ A_e= ____ Z_i= ____



______ A_e= ____ Z_i= ____

ACTIVITY SHEET D 4.2

ANSWER KEY

1. The Output signal is the result of the difference between signals applied to the inverting and noninverting inputs.

2. The difference between the input signal and the output signal with no feedback.

3. Gain bandwidth product--product of the closed-loop gain and closed-loop bandwidth of an operational amplifier.

   Common-mode rejection ratio--the ratio of the common-mode input voltage to the output voltage expressed in db.

   Offset current--a dc error voltage appearing at either input of a dc amplifier.

   Input voltage range--maximum voltage swing that can be applied to the inputs of the amplifier without damage to the amplifier.

   Inverting input--output signal is in phase with this input.

   Open loop voltage gain--the ratio of the change in voltage between the differential input terminals of an op amp to the corresponding change in output voltage, without feedback.

   Slew rate--the rate at which the output voltage can be driven through its dynamic range. Expressed as volts per microsecond.

4. $A_v = -R_1/R_1$

5. $A_v = (R_1/R_1) + 1$

6.

	741	LM118
input impedance	2M	3M
slew rate	.5V/µS	70V/µS
input offset voltage	1mV	2mV
open-loop gain	200,000	200,000

7.

A.	inverting	$A_e = 100$	$Z_i = 10k\Omega$
B.	inverting	$A_e = .01$	$Z_i = 1M\ \Omega$
C.	inverting	$A_e = 1$	$Z_i = 10k\Omega$
D.	noninverting	$A_e = 2$	$Z_i = 20k\Omega$

PROGRAM: ELECTRONICS

TASK: DIFFERENTIAL OPERATIONAL AMPLIFIERS

TASK #: D 4.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

USING A SCHEMATIC, ANALYZE, CONSTRUCT AND TROUBLESHOOT DIFFERENTIAL OPERATIONAL AMPLIFIERS.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 5 out of 6 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 5 out of 6 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

901

ELECTRONICS

DIFFERENTIAL OPERATIONAL AMPLIFIERS

D 4.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the required equipment used?	Y N
*2.	Was the required data recorded?	Y N
3.	Was the equipment used according to specifications?	Y N
*4.	Were all safety precautions followed?	Y N
5.	Was equipment returned to the proper storage area?	Y N
*6.	Was the experiment summarized properly?	Y N

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

DIFFERENTIAL OPERATIONAL AMPLIFIERS

EXAM

D 4.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Differential Operational Amplifiers. Choose the correct answer, (A or B), or complete the incomplete statement; then mark the corresponding answer on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, 80%.

DIFFERENTIAL OPERATIONAL AMPLIFIERS

EXAM

D 4.4

1. Operational amplifiers are nonlinear integrated circuit amplifiers.

   A. True
   B. False

2. The input impedance of an inverting operational amplifier is directly proportional to the value of the input resistor.

   A. True
   B. False

3. The open loop gain of an op-amp decreases as the frequency of the input signal increases from 100 Hertz to 10000 Hertz.

   A. True
   B. False

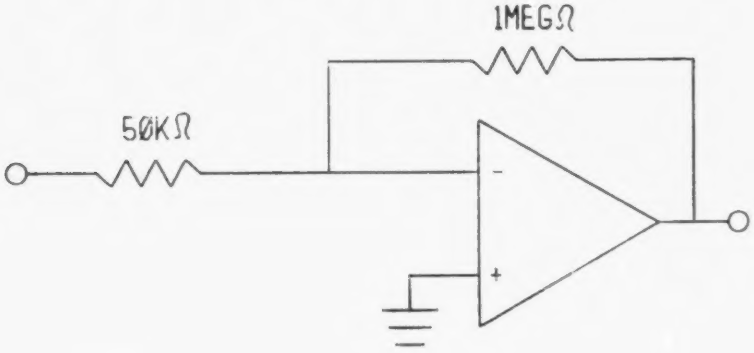
4. Operational amplifiers usually require two power supplies for proper operation.

   A. True
   B. False

5. The gain of a non-inverting amplifier can range from zero to open loop.

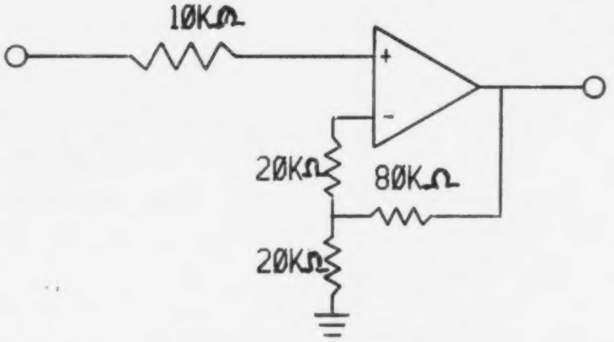
   A. True
   B. False

6. The gain of the following circuit is _______________.



EXAM D 4.4 CONT'D.

7. The gain of the following circuit is ______________.



8. The circuit in question 6 is a/an ______________ amplifier.

   A. inverting
   B. noninverting

9. The circuit in question 7 is a/an ______________ amplifier.

   A. inverting
   B. noninverting

10. The gain bandwidth product of an op-amp is a constant.

   A. True
   B. False

EXAM D 4.4

ANSWER SHEET

1. B
2. A
3. A
4. A
5. B
6. 20
7. 5
8. A
9. B
10. A

ELECTRONICS

ANALYZING ANALOG CIRCUITS

D 5: OPERATIONAL AMPLIFIER APPLICATIONS

TASK:	Explore industrial applications for operational amplifiers.
PURPOSE:	Because of the excellent characteristics of an operational amplifier there have been many circuits developed around the device. This learning guide will explain the terms and processes necessary to assist in the understanding of these applications.
OBJECTIVE:	Given a written exam you will explore industrial applications for operational amplifiers.

ESTIMATED CLASS TIME: 10 HOURS

OPERATIONAL AMPLIFIER APPLICATIONS

LEARNING STEPS

D 5

READ:	Information Sheet D 5.1, "Operational Amplifier Applications."
READ:	Information on operational amplifier applications from the following resource list.
COMPLETE:	Activity Sheet D 5.2, "Operational Amplifier Applications."
REVIEW:	Information Sheet D 5.1 and Activity Sheet D 5.2.
COMPLETE:	Laboratory performance on "Operational Amplifier Applications." Contact your instructor.
COMPLETE:	Performance Checklist D 5.3.
COMPLETE:	Written Exam D 5.4 for mastery of this task.

OPERATIONAL AMPLIFIER APPLICATIONS

RESOURCES

D 5

1. ELECTRONIC PRINCIPLES, 3rd Edition, by Malvino (McGraw-Hill, 1984).
2. ELECTRONICS IN INDUSTRY, 5th Edition, by Chute & Chute (McGraw-Hill, 1979).
3. ESSENTIALS OF SOLID STATE ELECTRONICS, by Faber (Wiley, 1985).
4. SEMICONDUCTOR TECHNOLOGY, by Weedon (Energy Concepts, Inc., 1985).
5. SOLID-STATE ELECTRONICS, 2nd Edition, by Rutkowski (Bobbs-Merrill, 1983).
6. Any appropriate electronics textbook

REQUIRED EQUIPMENT

0 - 25 VDC @ 1A Power Supply
0 - 40 VAC @ 1A Isolated Power Supply
0 - 1IMHZ Function Generator
10 MHZ Dual Trace Oscilloscope
Digital Multimeter

INFORMATION SHEET

D 5.1

OPERATIONAL AMPLIFIER APPLICATIONS

Operational amplifiers amplify the difference between two input signals. An application for an operational amplifier is as a differential amplifier used to detect differences between two input signals. This type of circuit is called a comparator. The circuit shown in Figure D 5.1-1 is a zero voltage comparator.

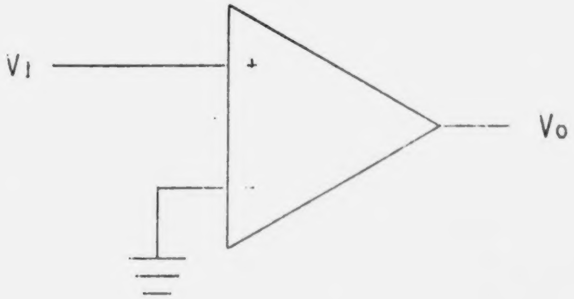


Figure D 5.1-1

A comparator requires that one of the inputs be connected to a reference voltage, and the unknown voltage connected to the other input. Using Figure D 5.1-2, the reference voltage is established by connecting the inverting input to the reference voltage V_{ref}. The unknown voltage is connected to the noninverting input. The amplifier is operating open loop gain. This allows the output voltage to switch rapidly between the supply voltages. An input signal below the reference voltage produces a negative output voltage. A signal above the reference voltage results in a positive output voltage.

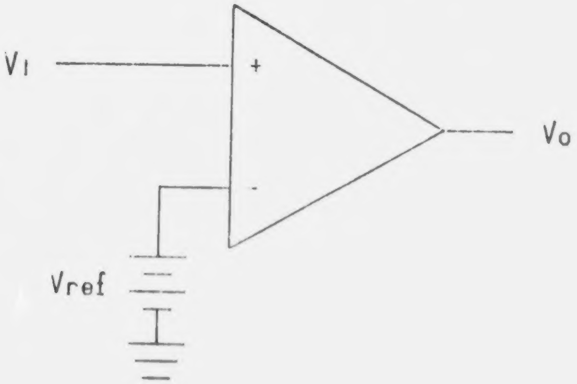


Figure D 5.1-2

Using Figure D 5.1-2 above the inverting input is held at zero volts. Supplying a sine wave to the noninverting input, the output waveform will be a square wave in phase with the input sine wave. If you reverse the input connections, and ground the noninverting input, the output waveform will be a square wave, 180° out-of-phase with the input sine wave.

A shortcoming of the simple comparator is that when its inputs are equal the output may switch rapidly from one supply voltage to the other. To alleviate this problem the circuit shown in Figure D 5.1-3 introduces **hysteresis** into the operation of an inverting comparator. A voltage divider is formed by R1 and R2 and connected between the output of the op-amp and ground. As the output of the comparator goes positive, the voltage applied to the noninverting input of the amplifier is positive. As the comparator's output becomes negative, the voltage applied to the noninverting input of the amplifier is negative. The two resulting voltages produced by the voltage dividers become two reference points for the incoming waveform. These are the upper trigger point (UTP) and the lower trigger point (LTP) respectively.

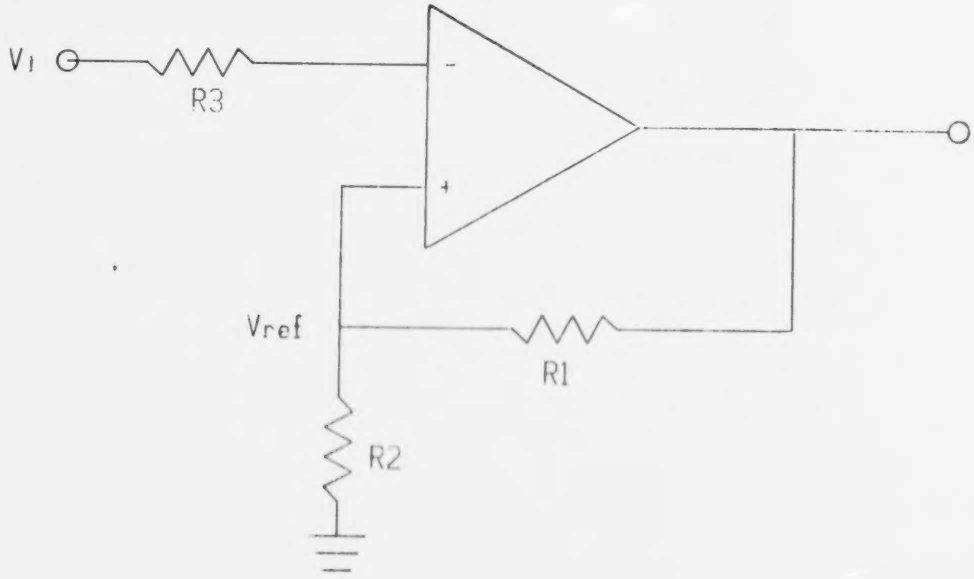


Figure D 5.1-3

When the input signal (even one containing unwanted electrical noise) reaches the UTP the output of the comparator will switch. The moment that the output starts to change, the voltage provided by the voltage divider changes in the opposite direction of the input voltage. This reduces the value of the UTP. This prevents the circuit from returning to its previous state. The UTP is the reference voltage and is connected to the noninverting input of the amplifier. This greater difference between the amplifier's inputs is amplified, insuring that the output will switch cleanly and quickly.

With the output negative the voltage divider produces a new reference voltage, the LTP. This produces a stable state for the amplifier. It will remain in this state until the input voltage reaches this new value. A Schmitt trigger is a comparator with hysteresis. The amount of hysteresis can be calculated using the following:

$$V_{HYS} = V_{VTP} - V_{LTP}$$

Where

$$V_{VTP} = [(R_2 / (R_1 + R_2)) (-V_{out(max)})]$$

and

$$V_{LTP} = [(R_2 / (R_1 + R_2)) (-V_{out(max)}]$$

Another application for which the op-amp is suited is the generation of sine waves and square waves. The schematic diagram in Figure D 5.1-4 shows a simple square wave generator or multivibrator. Added to the basic comparator circuit are a capacitor Cl and the feedback resistor Rf. Cl and Rf form an RC time constant. The charging voltage across Cl is the input to the amplifier. The frequency of the square wave generator may be determined by:

$$f_o = 1.1/RC$$

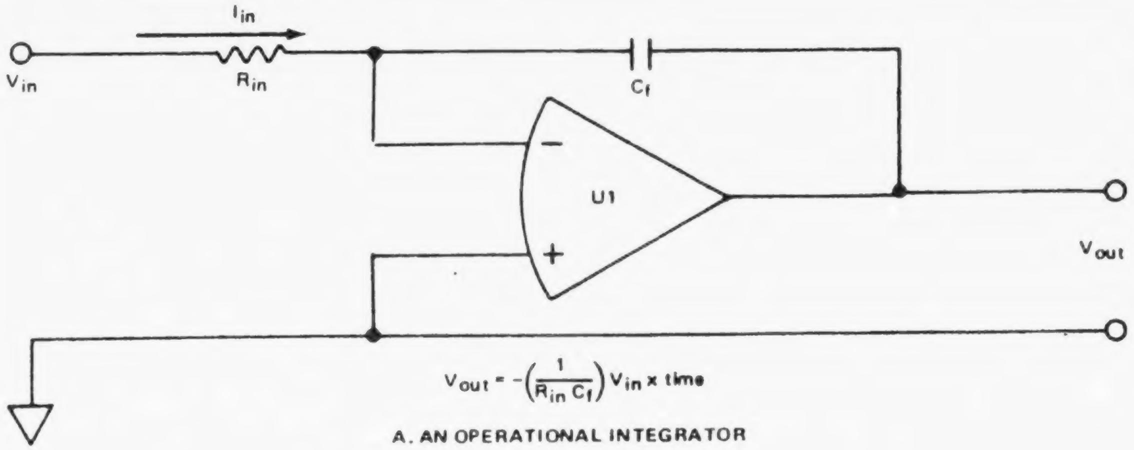
An entirely different circuit and its associated waveforms are shown below. This circuit is an operational amplifier integrator. The output voltage for the amplifier may be determined by:

$$V_{out} = \frac{1}{R_{in}C_f} V_{in} \times \text{time}$$

This circuit will give you the area under the curve for any complex waveform.

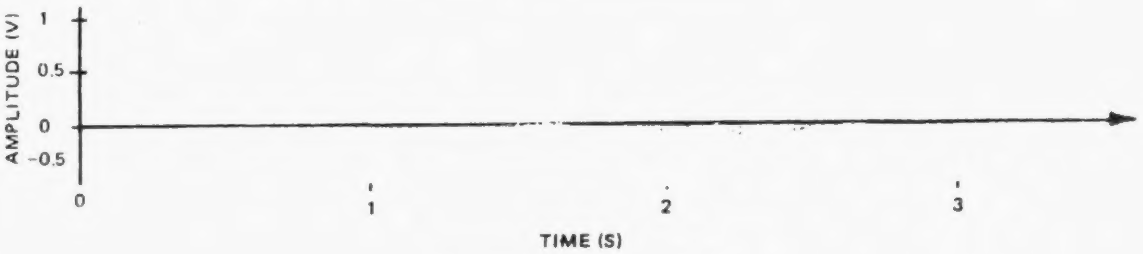
INFORMATION SHEET D 5.1 CONT'D.

OPERATIONAL AMPLIFIER INTEGRATOR

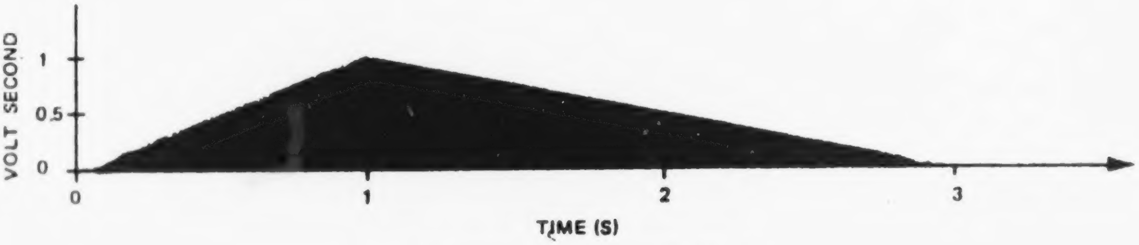


$$V_{out} = -\left(\frac{1}{R_{in}C_f}\right)V_{in} \times \text{time}$$

A. AN OPERATIONAL INTEGRATOR



B. SQUARE WAVE FUNCTION



C. INTEGRAL OF SQUARE WAVE

Figure D5.1-4

ACTIVITY SHEET

D 5.2

OPERATIONAL AMPLIFIER APPLICATIONS

1. Explain the operation of an operational amplifier comparator.

2. Define hysteresis.

3. Do the UTP and LTP for a Schmitt trigger need to be the same? Explain.

4. Explain the operation of an operational amplifier square-wave generator.

5. Explain the operation of an op-amp integrator.

6. Explain the operation of an op-amp differentiator.

7. Determine the circuit configuration of each of the operational amplifier circuits shown below.

8. Using the given input voltages, determine the output voltage for each of the operational amplifier circuits shown in Figure D 5.2-1.

*Assume each of these circuits is an ideal op amp and each input is +1.0 volt dc. Determine the output voltages.

ACTIVITY SHEET D 5.2 CONT'D.

Assume each of these circuits is an ideal op amp and each input is +1.0 volt dc. Determine the output voltages.

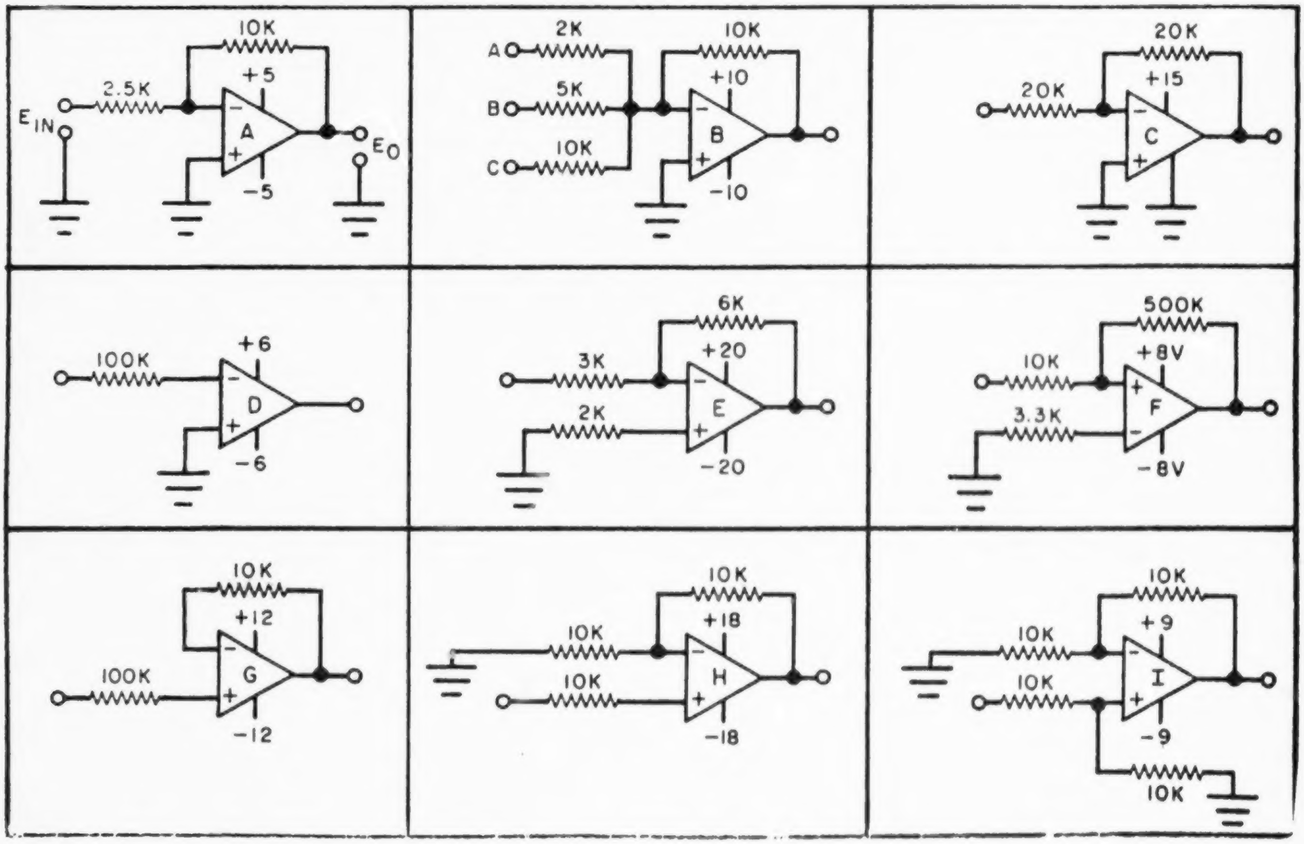

10K
2.5K
+5
-5
A
E_IN
E_O
2K
10K
5K
10K
+10
-10
B
A
B
C
20K
20K
+15
C
100K
+6
-6
D
6K
3K
2K
+20
-20
E
500K
10K
3.3K
+8V
-8V
F
10K
100K
+12
-12
G
10K
10K
10K
+18
-18
H
10K
10K
10K
10K
+9
-9
I

Figure D 5.2-1

ACTIVITY SHEET D 5.2

ANSWER SHEET

1. The amplifier amplifies any difference between the two inputs, thus comparing the two signals.

2. Nonlinearity in the response of an amplifier which depends upon the instantaneous input value and immediate past value.

3. No. They are set by the resistor combination.

4. Amplifier designed with positive feedback, causing the amplifier output to saturate a square-wave output.

5. The capacitor in the feedback circuit integrates the output voltage as it is fedback to the input of the amplifier.

   $dV_o/dt = -V_{IN}/RC$

6. The input capacitor responds only to the rate of change of the input signal and blocks the steady state (DC) input.

   $V_o = +/-RC(V_{ipp}/(T/2))$

7. A. Inverting Amplifier
   B. Inverting Summing Amplifier (3-Input)
   C. Inverting Amplifier (Single Ended)
   D. Inverting Amplifier (Zero-Comparator) Open Loop Gain
   E. Inverting Amplifier
   F. Noninverting Amplifier
   G. Noninverting Amplifier (Unity Gain)
   H. Noninverting Amplifier
   I. Noninverting Amplifier (Unity Gain)

8. A. -4V
   B. -8V
   C. 0V
   D. -6V
   E. -2V
   F. +8V
   G. +1V
   H. +2V
   I. +1V

PROGRAM: ELECTRONICS

TASK: OPERATIONAL AMPLIFIER APPLICATIONS

TASK #: D 5.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

EXPLORE INDUSTRIAL APPLICATIONS FOR OPERATIONAL AMPLIFIERS.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 5 out of 6 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 5 out of 6 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

OPERATIONAL AMPLIFIER APPLICATIONS

D 5.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the required equipment used?	Y N
*2.	Was the required data recorded?	Y N
3.	Was the equipment used according to specifications?	Y N
*4.	Were all safety precautions followed?	Y N
5.	Was equipment returned to the proper storage area?	Y N
*6.	Was the experiment summarized properly?	Y N

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

OPERATIONAL AMPLIFIER APPLICATIONS

EXAM

D 5.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Operational Amplifier Applications. Answer A or B (for True or False) to questions 1-10; follow directions for 11-13. Write your answers on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 11 out of 13 items correctly, 80%.

OPERATIONAL AMPLIFIER APPLICATIONS
EXAM

D 5.4

1. Hysteresis is used to increase the bandwidth of an operational amplifier.

   A. True
   B. False

2. A 74 op-amp can be used in the construction of a working 10 MHz square oscillator.

   A. True
   B. False

3. A 741 op-amp circuit with a gain of 10 will have a wider bandwidth than a similar circuit with a gain of 100.

   A. True
   B. False

4. Operational amplifiers can not amplify DC signals.

   A. True
   B. False

5. Op-amps use FET inputs to increase the input resistance of the amplifier.

   A. True
   B. False

6. The output of an operational amplifier integrator is directly proportional to the input signal.

   A. True
   B. False

7. In a differential amplifier, an increase in the voltage at the noninverting input causes a decrease in the output voltage.

   A. True
   B. False

8. The input impedance for an ideal noninverting operational amplifier is zero ohms.

   A. True
   B. False

EXAM D 5.4 CONT'D.

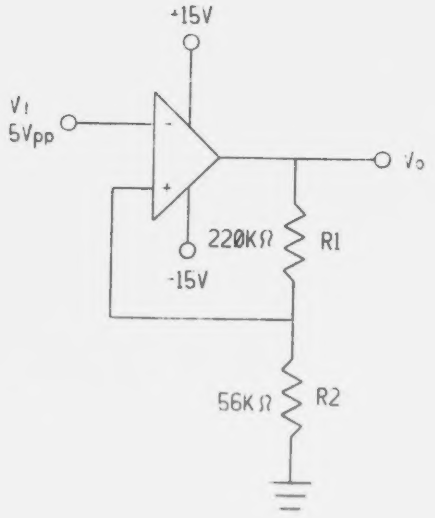
9. In a summing junction, the current entering the junction equals the current leaving the junction.

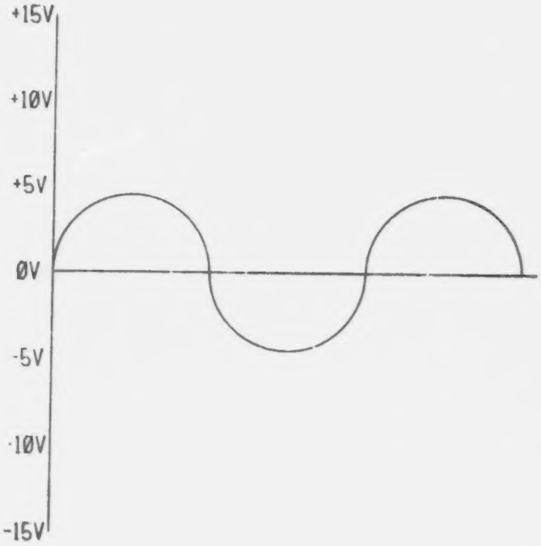
   A. True
   B. False

10. In an operational integrator, the basic feedback component is a capacitor.

   A. True
   B. False

11. Using the input waveform, draw the output waveform of the following circuit.





EXAM D 5.4 CONT'D.

12. Determine the circuit configuration of each of the operational amplifier circuits shown below.

13. Using the given input voltages, determine the output voltage for each of the operational amplifier circuits shown below.

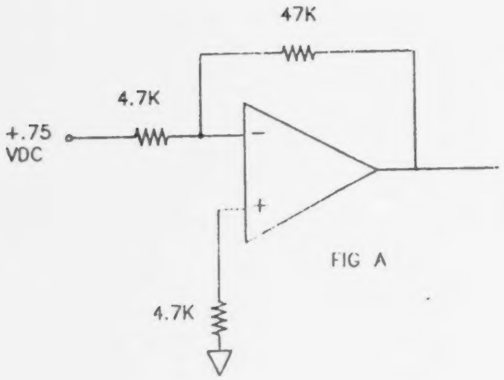

47K
4.7K
+.75
VDC
-
+
4.7K

FIG A

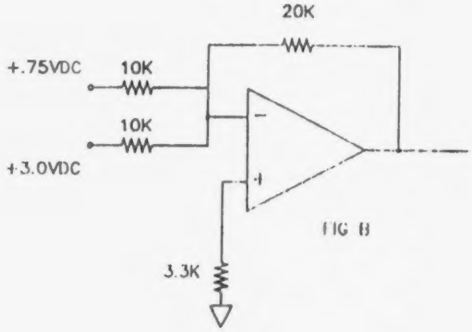

20K
+.75VDC
10K
10K
+3.0VDC
-
+
3.3K

FIG B

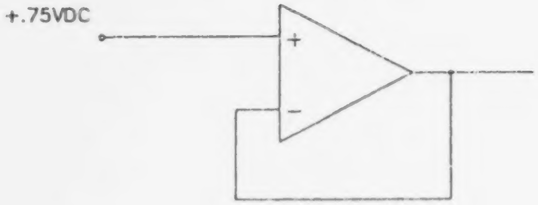


FIG C

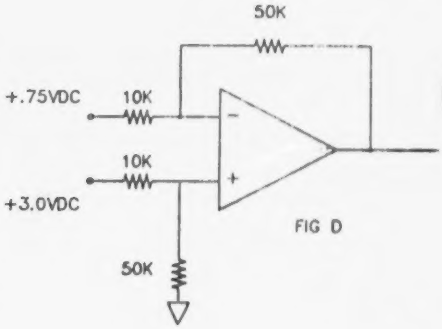

50K
+.75VDC
10K
10K
+3.0VDC
-
+
50K

FIG D

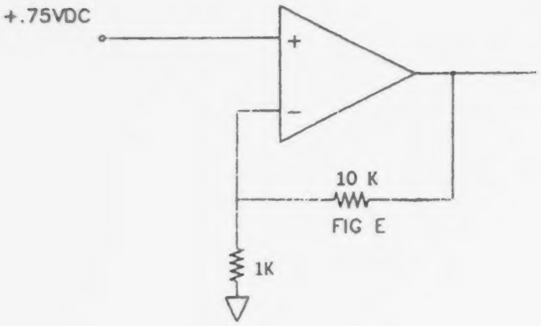

+.75VDC
+
-
10 K
1K

FIG E

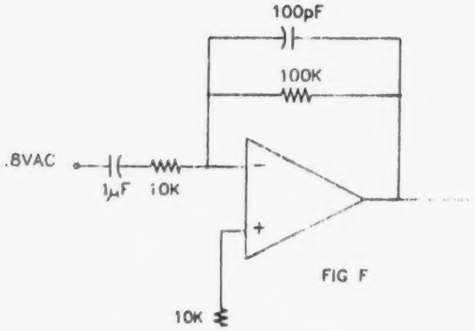

100pF
100K
.8VAC
1μF
10K
-
+
10K

FIG F

EXAM D 5.4

ANSWER SHEET

1. B

2. B

3. A

4. B

5. A

6. B

7. A

8. B

9. A

10. A

11. Inverted square wave passing through ± 3V on sine wave.

12.
    A. Inverting Amp
    B. Summing Amp
    C. Noninverting Amp
    D. Adder/Subtractor
    E. Noninverting Amp
    F. Integrator

13.
    A. -7.5 Vol
    B. -7.5 Vol
    C. .75 Vol
    D. -3.0 Vol
    E. 8.25 Vol
    F. 8 Vol

ELECTRONICS

ANALYZING ANALOG CIRCUITS

D 6: ACTIVE FILTERS

TASK:	Using a schematic, analyze, construct and troubleshoot active filters.
PURPOSE:	A major application of operational amplifiers is to construct active filters. This learning guide will explain the terms and processes necessary to assist in the understanding of these applications.
OBJECTIVE:	Given a written exam you will analyze active filters.

ESTIMATED CLASS TIME: 15 HOURS

ACTIVE FILTERS

LEARNING STEPS

D 6

READ: Information Sheet D 6.1, "Active Filters."

READ: Information on active filters in one of more of the references.

COMPLETE: Activity Sheet D 6.2, "Active Filters."

REVIEW: Information Sheet D 6.1, and Activity Sheet D 6.2.

COMPLETE: Laboratory performance on active filters. Contact your instructor.

READ: Information Sheet D 6.3, "Design of Active Filters."

READ: Information on design of active filters in one or more of the references.

COMPLETE: Activity Sheet D 6.4, "Design of Active Filters."

REVIEW: Information Sheet D 6.3, and Activity Sheet D 6.4.

COMPLETE: Laboratory performance on active filters. Contact your instructor.

COMPLETE: Performance Checklist D 6.5.

COMPLETE: Written Exam D 6.6 for mastery of this task.

ACTIVE FILTERS

RESOURCES

D 6

1. ELECTRONIC PRINCIPLES, 3rd Edition, by Malvino (McGraw-Hill, 1984).
2. ELECTRONIC TROUBLESHOOTING, by Oleksy (Bobbs-Merrill, 1983).
3. ELECTRONICS IN INDUSTRY, 5th Edition, by Chute & Chute (McGraw-Hill, 1979).
4. ESSENTIALS OF SOLID STATE ELECTRONICS, by Faber (Wiley, 1985).
5. SEMICONDUCTOR TECHNOLOGY, by Weedon (Energy Concepts, Inc., 1985).
6. SOLID-STATE ELECTRONICS, 2nd Edition, by Rutkowski (Bobbs-Merrill, 1983).
7. Any appropriate electronics textbook

REQUIRED EQUIPMENT

0 - 25 VDC @ 1A Power Supply
0 - 40 VAC @ 1A Isolated Power Supply
0 - 1IMHZ Function Generator
10 MHZ Dual Trace Oscilloscope
Digital Multimeter

INFORMATION SHEET

D 6.1

ACTIVE FILTERS

A very common application of operational amplifiers is in the area of active filters. A filter is a device that passes electric currents at certain frequencies and prevents the passage of all other frequencies. An active filter is a circuit consisting of resistors, capacitors, and an op-amp. Just as with passive filters, active filters may be designed as high-pass, low-pass, or band-pass filters.

An operational amplifier, when connected as a voltage follower with the correct arrangement of resistors and capacitors, can become a high-pass filter. The circuit in Figure D 6.1-1 shows the construction of a high-pass operational amplifier active filter. The cutoff frequency f_c can be determined by using the equation:

$$f_c = \frac{1}{2\sqrt{R_1R_2C_1C_2}}$$

For this equation to work, R1 has to be equal to R2, and C1 has to be equal to twice the value of C2.

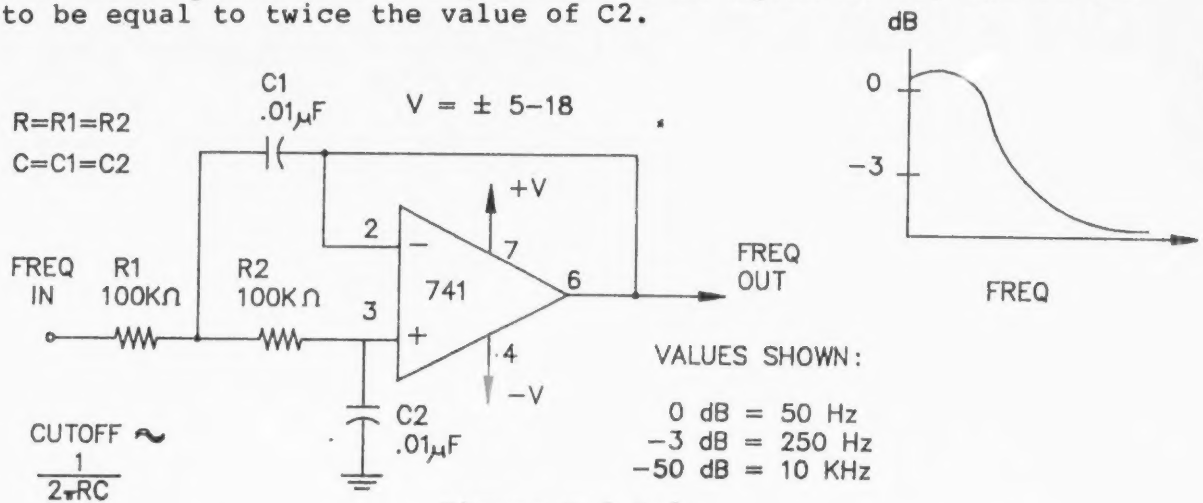

R=R1=R2
C=C1=C2
C1
.01μF
V = ± 5–18
+V
2
7
741
6
3
4
−V
FREQ IN
R1 100KΩ
R2 100KΩ
FREQ OUT
C2
.01μF
CUTOFF ~ $\frac{1}{2\pi RC}$
VALUES SHOWN:
0 dB = 50 Hz
−3 dB = 250 Hz
−50 dB = 10 KHz
dB
0
−3
FREQ

Figure D 6.1-1

The following equation states the process for determining the change in resistive values necessary to achieve a desired change in the cutoff frequency.

$$R_{new} = R_{old} \times \frac{f_{c(old)}}{f_{c(new)}}$$

The same voltage follower is shown in Figure D 6.1-2 with the arrangement of the resistors and capacitors reversed. As you would guess, this circuit represents a low-pass filter.

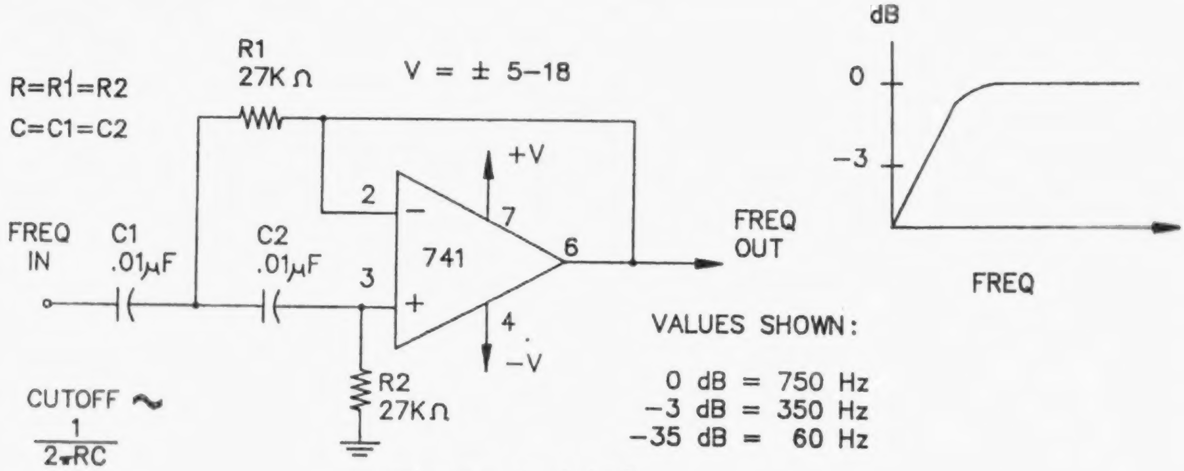

R=R1=R2
C=C1=C2
R1
27KΩ
V = ± 5–18
+V
2
7
FREQ IN
C1
.01μF
C2
.01μF
3
741
6
FREQ OUT
4
–V
R2
27KΩ
CUTOFF ~ $\frac{1}{2\pi RC}$
VALUES SHOWN:
0 dB = 750 Hz
–3 dB = 350 Hz
–35 dB = 60 Hz
dB
0
–3
FREQ

Figure D 6.1-2

The procedures for determining the cutoff frequency and changing the cutoff frequency are the same as for the high-pass filter. If you have not discovered it yet, the frequency can be adjusted by substituting capacitance for the resistance in the frequency equation and solving for the new frequency. Also, it is possible to change both the resistance and capacitance at the same time. It is necessary that R1 equal R2 and that C1 equal twice the value of C2.

A combination of a low-pass and a high-pass resistor capacitor circuit arrangement will result in the bandpass filter shown in Figure D 6.1-3.

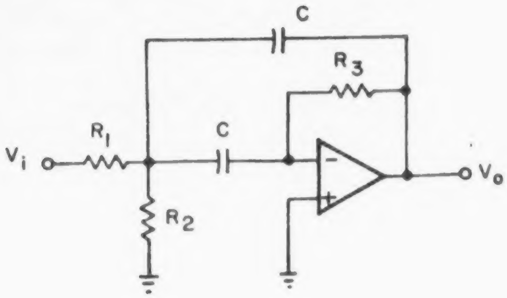

C
R3
R_1
C
V_i
V_o
R_2

Figure D 6.1-3

INFORMATION SHEET D 6.1 CONT'D.

In this circuit there is a center frequency, and it is determined from the equation:

$$f_o = \frac{1}{2\pi C} \left[\frac{1}{2\ R_3} \ X\ \frac{R_1 + R_2}{R_1\ R_2} \right]^{1/2}$$

This can be simplified to the following for each of the the three resistors where G_o is the desired gain at the center frequency f_o.

$$R_1 = \frac{Q}{2\pi f_o G_o C}$$

$$R_3 = 2R_1G_o$$

and

$$R_2 = \frac{Q}{2\pi f_o C(2Q^2 - G_o)}$$

Just as with the other filters, a new frequency can be determined using the equation:

$$R_{2(new)} = R_{2(old)}\ X \left(\frac{f_{old}}{f_{new}} \right)^2$$

When a bandpass filter is connected in series between the source and the load, it passes the band of frequencies from the source to the load. Thus its name, a bandpass filter. However, if the same amplifier is connected in parallel with the load, it will pass the same frequencies to ground preventing them from reaching the load, while allowing all the other frequencies to reach the load. When connected this way, the filter looks to the load device like a bandstop filter.

ACTIVITY SHEET

D 6.2

ACTIVE FILTERS

1. Define bandpass filter, bandstop filter, low-pass filter, and high-pass filter.
2. Explain the advantages of using an operational amplifier to construct a low-pass active filter.
3. Explain the process for determining the cutoff frequencies for high and low pass filters.
4. Explain the process for determining the center frequency for a bandpass active filter.
5. Explain the effects of changing the values of the capacitors and resistors in each of the three types of active filters discussed.
6. Explain the operation of a notch filter.
7. Design a low-pass filter to be -3dB at 100 Hz.
8. Design a high-pass filter to be -3dB at 100 Hz.

ACTIVITY SHEET D 6.2

ANSWER SHEET

1. bandpass filter - passes only those frequencies within the upper and lower cutoff points

   bandstop filter - stops only those frequencies within the upper and lower cutoff points

   low-pass filter - passes only those frequencies below the cutoff point

   high-pass filter - passes only those frequencies above the cutoff point

2. Smaller components, less cost, no loss

3. See instructor.

4. See instructor.

5. See instructor.

6. Same as a band-stop or band-reject filter

7. See instructor.

8. See instructor.

INFORMATION SHEET

D 6.3

DESIGN OF ACTIVE FILTERS

The schematic diagram of a low-pass filter is shown in Figure D 6.3-1 below.

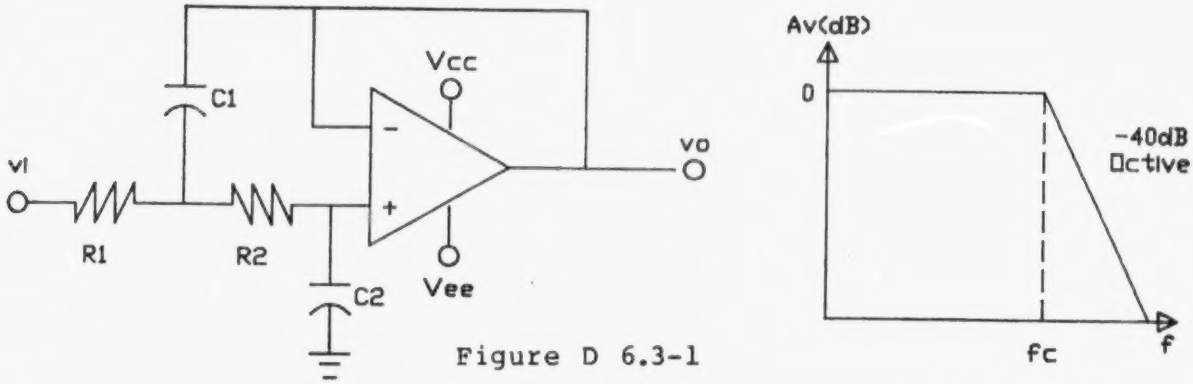


Figure D 6.3-1

One of the RC networks is constructed using R_1 and C_1; the other R_2 and C_2. Remember the critical frequency of this design is determined as:

$$F_c = 1/2\ \pi\ \sqrt{R_1R_2C_1C_2}$$

And that the critical frequency occurs when the gain of the filter decreases to .707 or -3dB.

To insure maximum flatness in the circuit's response, the following conditions must exist in the circuit. C_1 is twice the value of C_2 and R_1 is equal in value to R_2. With this knowledge, the formula and using the earlier schematic diagram for reference, let's design a two-pole Butterworth filter with a critical frequency of 6kHz.

To prevent excessive loading of the source, let's pick a moderate value of 22k ohms for R_1 and R_2. To determine the values for the capacitors, we must simplify the earlier equation.

$$f_c = 1/2\ \pi\ \sqrt{R_1R_2C_1C_2}$$

$$f_c^2 = 1/4\quad \pi^2R_1R_2C_1C_2$$

We know that $C_1 = 2C_2$ and $R_1 = R_2$. Thus

$$f_c^2 = 1/4\quad \pi^2R^2(2C_2^2)$$

INFORMATION SHEET D 6.3 CONT'D.

Solving this for C_2 results in

$$C_2^2 = 1/8 \quad \pi^2 R^2 f_t^2$$

Taking the square root of each side

$$C_2 = 1/2 \cdot \pi \quad \sqrt{2\ Rf_c}$$

$$= 0.707/2\ Rf_c$$

$$= 0.707/2 \quad (22k\Omega)(6kHz)$$

$$C_2 = 0.0034\mu F$$

and with $C_1 = 2C_2$

$$C_1 = 2(0.0034)$$

$$C_1 = 0.0068\mu F$$

The schematic diagram in Figure D 6.3-2 shows the component rearrangement for a high-pass Butterworth filter.

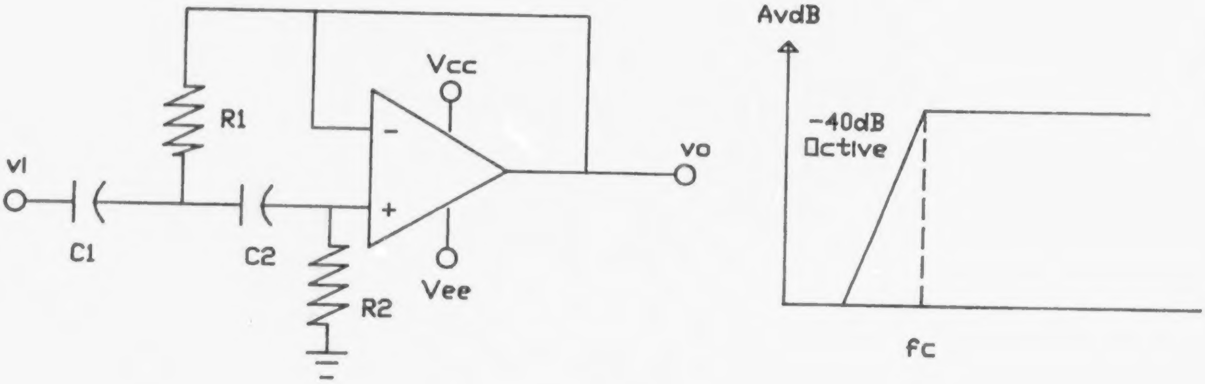


Figure D 6.3-2

The design of such a filter is similar to the low-pass except that the resistors are the calculated variables. In this type of Butterworth filter, R_1 is twice the value of R_2 and C_1 is equal to C_2. Using this information and Figure D 6.3-2 let's review the design of a high-pass filter with a critical frequency of 5kHz. From reading and experience, let's choose a value of 0.002uF for the capacitors.

$$f_c = 1/2\,\pi\,\sqrt{R_1 R_2 C_1 C_2}$$

$$f_c^{\,2} = 1/4\,\pi^2\,R_1 R_2 C_1 C_2$$

We know that $R_2 = 2R_1$ and $C_1 = C_2$. Thus

$$f_c^{\,2} = 1/4\pi^2(2R_1^{\,2})C^2$$

Solving this for R_1 results in

$$R_1^{\,2} = 1/8\,\pi^2\,C^2 f_c^{\,2}$$

Taking the square root of each side

$$R_1 = 1/\sqrt{2}\quad 2\pi C f_c$$

$$= 0.707/2\pi C f_c$$

$$= 0.707/2\pi(0.002\mu F)(5kHz)$$

$$= 11252\,\Omega$$

$$R_1 = 0.0034\mu F$$

and with $R_2 = 2R_1$

$$R_2 = 2(11252\,\Omega)$$

$$R_2 = 22500\,\Omega$$

Another method of implementing a band-pass filter is to cascade a high-pass Butterworth filter followed by a low-pass Butterworth filter. This arrangement is shown in Figure D 6.3-3.

2-POLE HIGH PASS

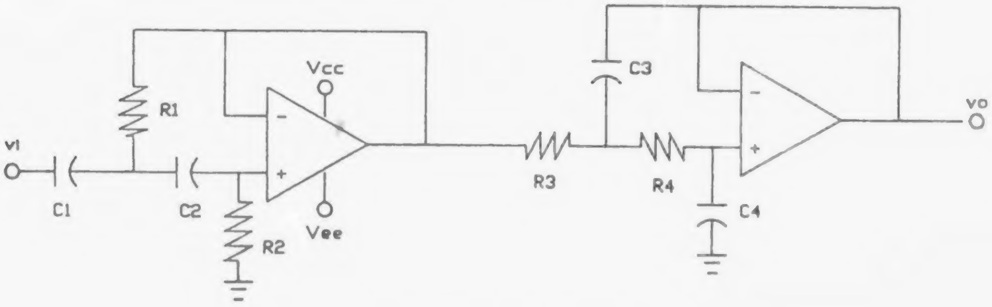


Figure D 6.3-3

Each of the filters is a two-pole configuration resulting in a roll-off of 40dB/decade. The combined response curve for the filter is shown in Figure D 6.3-4.

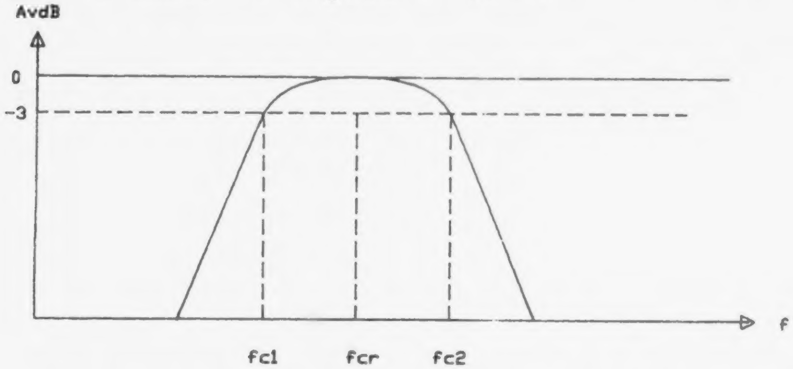


Figure D 6.3-4

The critical frequency for the filter is determined using the formula

$$f_c = 1/2\pi\sqrt{R_X R_Y C_X C_Y}$$

where X and Y are the component subscripts.

Using this formula as in the previous circuit, let's determine the bandwidth and center frequency using the values shown.

The critical frequency for the high-pass filter is

$$f_{c1} = 1/2\pi\sqrt{R_1 R_2 C_1 C_2}$$

$$= 1/2\pi\sqrt{(50k\Omega)(25k\Omega)(.01\mu F)(.01\mu F))}$$

$$= 450Hz$$

The critical frequency for the low pass filter is found using the same formula with the other values resulting in

f_{c2} = 1500 Hz

The bandwidth for the filter at -3dB is determined by obtaining the difference between the two critical frequencies.

$BW = f_{c2} - f_{c1}$

$= 1500 - 450$

$= 1050Hz$

INFORMATION SHEET 6.3 CONT'D.

The center frequency is determined by using the following:

$$f_r = \sqrt{f_{c1}f_{c2}}$$

$$= \sqrt{(1500\text{Hz X } 450\text{Hz})}$$

$$= 822\text{Hz}$$

ACTIVITY SHEET

D 6.4

DESIGN OF ACTIVE FILTERS

1. Design a low-pass Butterworth filter with a critical frequency of 3kHz. Use resistor values of 22k ohms.
2. Construct and verify the filter circuit designed in question 1.
3. Design a high-pass Butterworth filter with a critical frequency of 1kHz. Use capacitor values of .015µF.
4. Construct and verify the filter circuit designed in question 3.
5. Combine the circuits designed in questions 1 and 3 into a band-pass filter and determine its bandwidth and center frequency.
6. Construct and verify the combined circuit designed in question 5.

ACTIVITY SHEET D 6.4

ANSWER SHEET

1. $C_1 = 0.0034\mu F$ $C_2 = 0.0017\mu F$
2. Actual response will depend upon the tolerance of the RC components.
3. $R_1 = 7.07k\Omega$ $R_2 = 14.1k\Omega$
4. Actual response will depend upon the tolerance of the RC components.
5. BW = 2kHz $f_r = 1732Hz$
6. Actual response will depend upon the tolerance of the RC components.

PROGRAM: ELECTRONICS

TASK: ACTIVE FILTERS

TASK #: D 6.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE __________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT __________

TERMINAL PERFORMANCE OBJECTIVE:

USING A SCHEMATIC, ANALYZE, CONSTRUCT AND TROUBLESHOOT ACTIVE FILTERS.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 5 out of 6 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 5 out of 6 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

ACTIVE FILTERS

D 6

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the required equipment used?	Y N
*2.	Was the required data recorded?	Y N
3.	Was the equipment used according to specifications?	Y N
*2.	Was the required data recorded?	Y N
*4.	Were all safety precautions followed?	Y N
5.	Was equipment returned to the proper storage area?	Y N
*6.	Was the experiment summarized properly?	Y N

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

ACTIVE FILTERS

EXAM

D 6.6

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Active Filters. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, 80%).

ACTIVE FILTERS

EXAM

D 6.6

1. Doubling the size of the capacitors on a low-pass filter will __________ the cutoff frequency.

   A. raise
   B. lower

2. Doubling the size of the capacitors on a high-pass filter will __________ the cutoff frequency.

   A. raise
   B. lower

3. Doubling the size of the capacitors on a band-pass filter will __________ the center frequency.

   A. raise
   B. lower

4. Doubling the size of the resistors on a low-pass filter will __________ the cutoff frequency.

   A. raise
   B. lower

5. Doubling the size of the resistors on a high-pass filter will __________ the cutoff frequency.

   A. raise
   B. lower

6. Doubling the size of the resistors on a band-pass filter will __________ the center frequency.

   A. raise
   B. lower

7. Connecting a band-pass filter in parallel with the load produces the same effect as a band-stop filter in series with the load.

   A. True
   B. False

8. Notch filter is another name for a low-pass filter.

   A. True
   B. False

9. The greater the bandwidth of a low-pass filter, the greater its gain.

   A. True
   B. False

10. The roll-off for a two-pole Butterworth filter is -40dB/decade.

    A. True
    B. False

EXAM D 6.6

ANSWER KEY

1. B
2. B
3. B
4. B
5. B
6. B
7. A
8. B
9. B
10. A

ELECTRONICS

ANALYZING ANALOG CIRCUITS

D 7: SOLID STATE OSCILLATORS

TASK:	Using a schematic, analyze, construct and troubleshoot solid state oscillators.
PURPOSE:	Many devices require circuits that produce wave forms of various shapes. One type of circuit that produces a symmetrical waveform is an oscillator. This learning guide will explain the terms and processes necessary to assist in the understanding of oscillator circuits.
OBJECTIVE:	Given a written exam you will analyze oscillators.

ESTIMATED CLASS TIME: 15 HOURS

SOLID STATE OSCILLATORS

LEARNING STEPS

D 7

READ: Information Sheet D 7.1, "Transistor Oscillators."

READ: Information on transistor oscillators from the following resource list.

COMPLETE: Activity Sheet D 7.2, "Transistor Oscillators."

REVIEW: Information Sheet D 7.1 and Activity Sheet D 7.2.

COMPLETE: Laboratory performance on transistor oscillators. Contact your instructor.

READ: Information Sheet D 7.3, "Operational Amplifier Oscillators."

READ: Information on operational amplifier oscillators in one or more of the references.

COMPLETE: Activity Sheet D 7.4, "Operational Amplifier Oscillators."

REVIEW: Information Sheet D 7.3 and Activity Sheet D 7.4.

COMPLETE: Laboratory performance on operational amplifier oscillators. Contact your instructor.

COMPLETE: Performance Checklist D 7.5.

COMPLETE: Written exam D 7.6 for mastery of this task.

SOLID STATE OSCILLATORS

RESOURCES

D 7

1. ELECTRONIC PRINCIPLES, 3rd Edition, by Malvino (McGraw-Hill, 1984).
2. ELECTRONICS IN INDUSTRY, 5th Edition, by Chute & Chute (McGraw-Hill, 1979).
3. ESSENTIALS OF SOLID STATE ELECTRONICS, by Faber (Wiley, 1985).
4. SEMICONDUCTOR TECHNOLOGY, by Weedon (Energy Concepts, Inc., 1985).
5. SOLID-STATE ELECTRONICS, 2nd Edition, by Rutkowski (Bobbs-Merrill, 1983).
6. Any appropriate electronics textbook

REQUIRED EQUIPMENT

0 - 25 VDC @ 1A Power Supply
0 - 40 VAC @ 1A Isolated Power Supply
0 - 1IMHZ Function Generator
10 MHZ Dual Trace Oscilloscope
Digital Multimeter

INFORMATION SHEET

D 7.1

TRANSISTOR OSCILLATORS

It is possible to design a transistor circuit to operate as an oscillator. This type of circuit feeds back a portion of the output signal in phase to the input of the circuit. This positive feedback causes the circuit to oscillate. There are many different types of circuit configurations that are oscillators. Some of the major types will be presented in this unit.

The first oscillator is the phase-shift oscillator shown in Figure D 7.1-1 in two configurations, using an op-amp and a FET. The amplifier has a 180° phase shift due to its configuration. The output of the amplifier is fed back to the input through three cascaded lead networks. Remember that a lead network produces a phase shift between 0° and 90° depending on the frequency of the input signal. Thus at a unique frequency the total phase shift of the three networks will be exactly 180°. This will result in a total phase shift of 360° which feeds the output back to the input in phase. The circuit will oscillate at this frequency. The frequency of the oscillator can be determined by:

$$f_o = \frac{1}{2\pi RC\sqrt{6}}$$

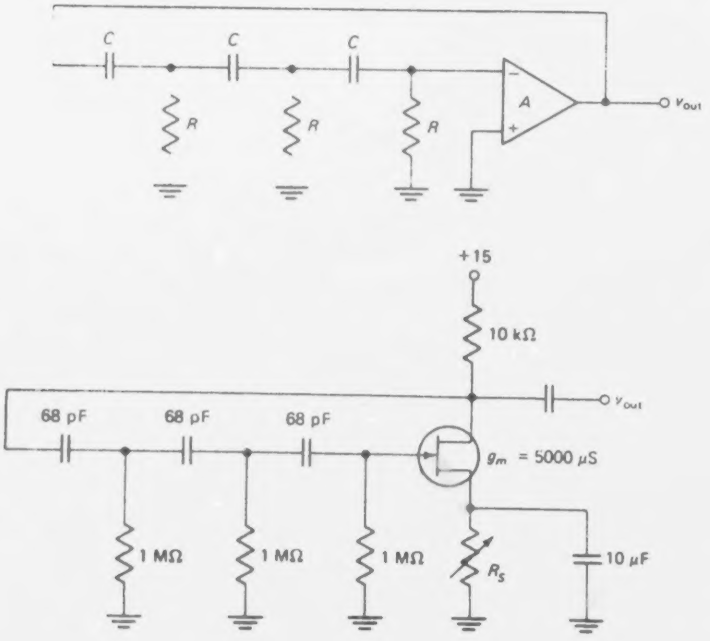


Figure D 7.1-1

INFORMATION SHEET D 7.1 CONT'D.

The Wein-bridge oscillator is another circuit that is used for frequencies between 5 Hz and 1 MHz. This circuit is shown in Figure D 7.1-2. Just like all other oscillators, the output must be fed back in phase to the input at one frequency and out of phase at all other frequencies.

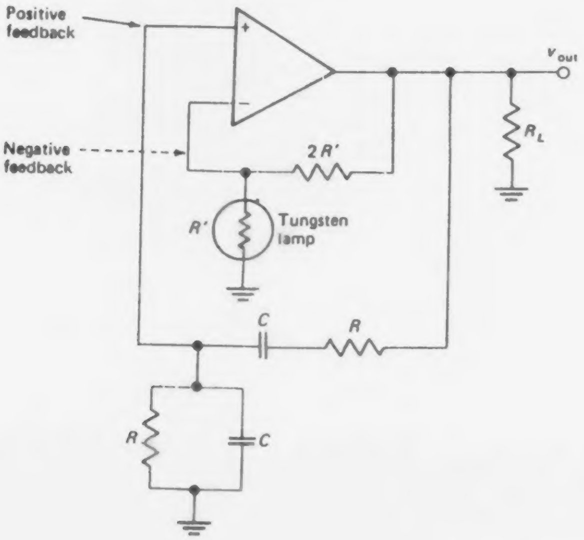


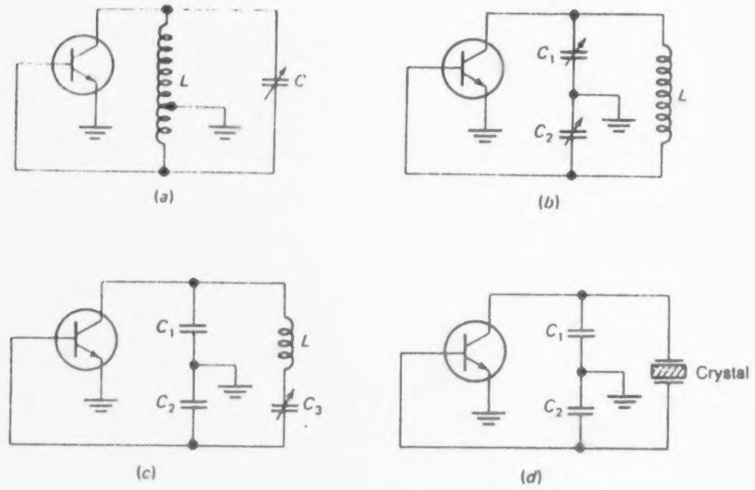
Figure D 7.1-2

The frequency of a Wein-bridge oscillator is determined by:

$$f_o = \frac{1}{2\pi RC}$$

This enables the frequency to be adjusted by varying the value of R and/or C.

A different type of oscillator is the LC oscillator which consists of the Hartley, Colpitts, and Clapp oscillators. The simplified schematics of each circuit are shown below along with the crystal oscillator. This group of oscillators is used at frequencies between 1 MHz and 500 MHz. With an amplifier and the LC resonant circuit, a signal is fed back with the correct amplitude and phase to sustain oscillation.



(a) Hartley. (b) Colpitts. (c) Clapp. (d) Crystal.

Figure D 7.1-3

In the Hartley oscillator Figure D 7.1-3a, the LC tank is resonant at the desired frequency. This produces a 180° phase shift because of the tapped inductor and the common emitter configuration produces the other 180°. The Hartley oscillator is used in many transistor radios and other products.

The Colpitts oscillator Figure D 7.1-3b, a better circuit, is used in commercial signal generators. This oscillator uses a tapped capacitance instead of an inductor. By gang-tuning the two capacitors, the frequency of oscillation can be varied. The Clapp oscillator Figure D 7.1-3c is a variation of the Colpitts oscillator with a capacitor added to the inductive branch of the tank circuit. This makes the Clapp a much more stable oscillator than the Colpitts circuit.

The operating frequency of the above oscillators can be determined by:

$$f_o = \frac{1}{2 \quad \sqrt{LC}}$$

when the Q of the tank circuit is greater than 10.

To obtain a much more stable oscillator, the inductor of the Colpitts oscillator is replaced by a crystal Figure D 7.1-3d. The crystal has a much higher Q than the inductor. This results in a very stable oscillator with its frequency determined by the resonant frequency of the crystal.

The circuit in Figure D 7.1-4 is the schematic diagram of a unijunction, relaxation oscillator. This circuit uses a special transistor called a unijunction transistor. When collected into the circuit as shown, a sawtooth output waveform is produced. The approximate frequency of the oscillation is determined by:

$$f_o \cong RC$$

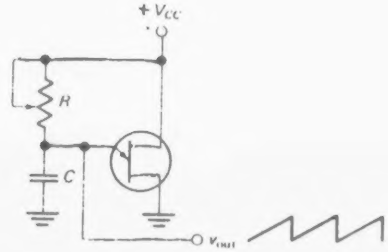


Figure D 7.1-4

The troubleshooting of oscillators is the same as for an amplifier, because an oscillator circuit is just an amplifier with positive feedback. The circuits need dc bias voltages just like an amplifier.

There are also problems specific to oscillators. For example, the frequency of the oscillator is usually determined by some type of filter or crystal. If there is a problem with the stability or frequency of operation, the cause will usually be located in these components. If the circuit refuses to oscillate, the problem is usually related to insufficient feedback. This may be caused by problems in the feedback loop, or insufficient gain in the transistor or operational amplifier.

ACTIVITY SHEET

D 7.2

TRANSISTOR OSCILLATORS

1. Explain the operation of a phase-shift oscillator.
2. Explain the operation of a Wein-bridge oscillator.
3. Explain the operation of a Hartley oscillator.
4. Explain the operation of a Colpitts oscillator.
5. Explain the operation of a Clapp oscillator.
6. Explain the operation of a crystal oscillator.
7. Explain the operation of a unijunction oscillator.
8. Which of the above oscillators is the best for frequencies below 1 MHz? Explain.
9. Which of the above oscillators is the best for stability? Explain.
10. What types of problems are usually associated with the operation of oscillators?
11. Design a RC UJT oscillator with a frequency of 1K Hz.

ACTIVITY SHEET D 7.2

ANSWER SHEET

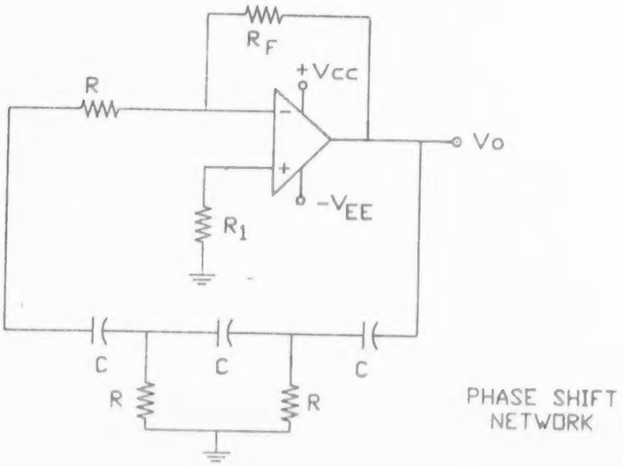
1. Uses RC networks to achieve 180° phase shift and 180° phase shift of amplifier for a total of 360° phase shift between input and output, resulting in regenerative feedback and oscillation.
2. Produces regenerative feedback using an LC tank circuit.
3. Produces regenerative feedback using a tapped capacitor configuration.
4. Improved version of the Colpitts.
5. Crystal in a version of the Colpitts oscillator provides a higher Q and produces a more stable frequency.
6. Charging and discharging of RC combination using a unijunction transistor as the discharge device. Output taken from either base or the emitter.
7. Phase shift or relaxation oscillator. Other oscillators do not function well because of need for large inductors or capacitors.
8. Crystal because of the crystal's resonance and high Q.
9. Failure to start oscillating, frequency instability.
10. Circuit should be configured properly and have an RC value of approximately one millisecond.
11. Circuit should function as designed within tolerance.

INFORMATION SHEET

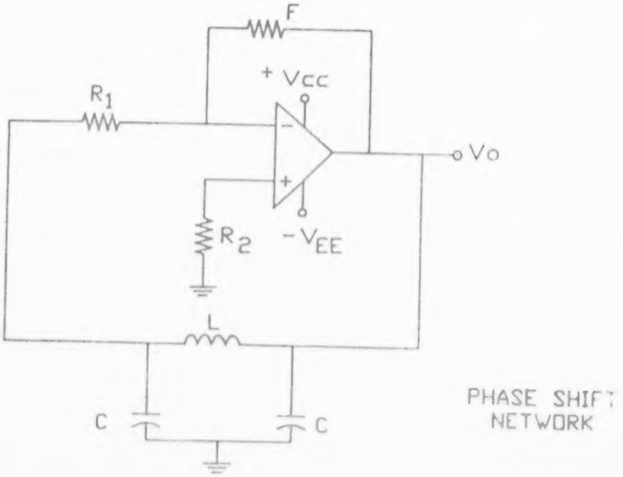
D 7.3

OPERATIONAL AMPLIFIER OSCILLATORS

Operational amplifiers may be used in place of transistors in the design of many oscillators. Figure D 7.3-1 shows the schematic diagrams of a phase shift oscillator and a Colpitts oscillator using an operational amplifier in its inverting configuration.


R
R_F
+Vcc
Vo
-V_EE
R_1
C
C
C
R
R
PHASE SHIFT NETWORK

PHASE SHIFT OSCILLATOR


F
R_1
+ Vcc
Vo
R_2
-V_EE
L
C
C
PHASE SHIFT NETWORK

COLPITTS OSCILLATOR

Figure D 7.3-1

The Wein-bridge oscillator is another circuit that is used for frequencies between 5 Hz and 1 MHz. This circuit uses an operational amplifier as shown in Figure D 7.3-2. As with all other oscillators, the output must be fed back in phase to the input at one frequency and out of phase at all other frequencies.

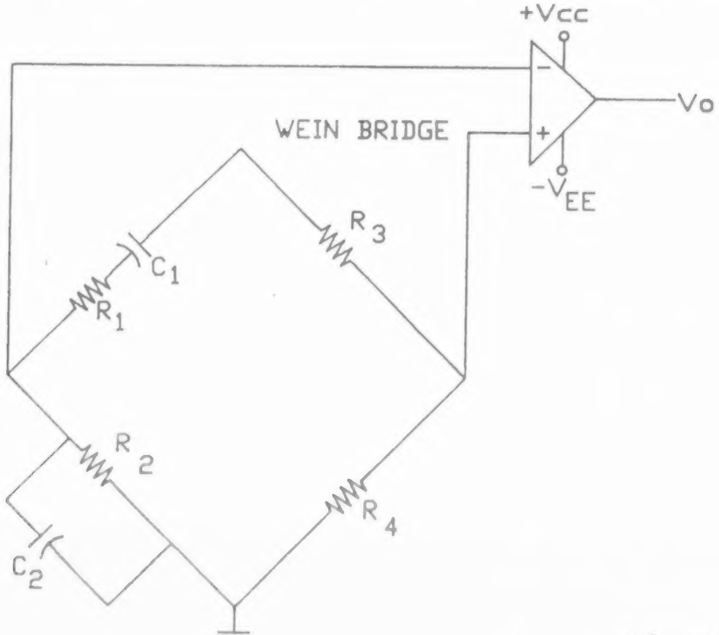


Figure D 7.3-2

The frequency of a Wein-bridge oscillator is determined by:

$$f_o = \frac{1}{2\pi RC}$$

This enables the frequency to be adjusted by varying the value of R and/or C.

In Figure D 7.3-3 the bridge components are shown enclosed within the dotted lines. Investigation of the bridge circuit indicates that the circuit is balanced when:

$$R_3/R_4 = (R_1/R_2) + (C_2/C_1)$$

$$2\pi f = 1\sqrt{R_1C_1R_2C_2}$$

If we let $R_1 = R_2 = R$ and $C_1 = C_2 = C$ in the equation above results in

$$f = 1/2\pi RC$$

and similarly

$$R_3 = 2R_4$$

The voltage gain for the amplifier will be $A_v = (R_3 + R_4)/R_4 = 3$. This results in a feedback network attentuation of 1/3. This requires that the gain, A_v must be greater than 3 for the oscillator to operate.

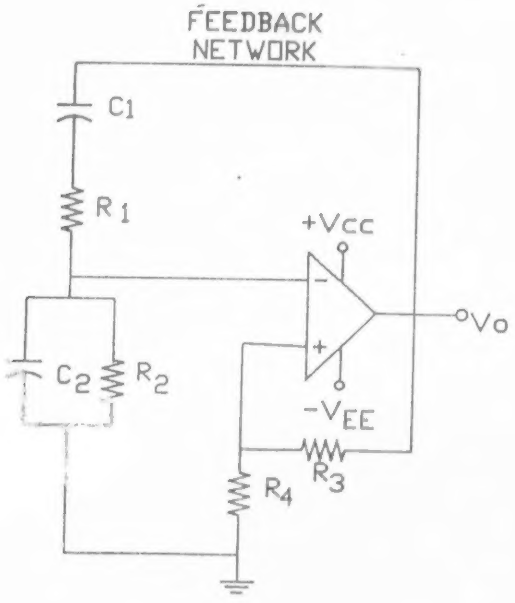

FEEDBACK
NETWORK
C1
R1
+Vcc
Vo
C2
R2
-VEE
R3
R4

Figure D 7.3-3

The previous circuit is redrawn in Figure D 7.3-4 and given values using a 741 operational amplifier. The circuit is actually a noninverting amplifier with two legs of the bridge in the feedback circuit as shown. At resonance the voltage fed back from the output is in phase with the input. At all other frequencies the bridge is out of balance.

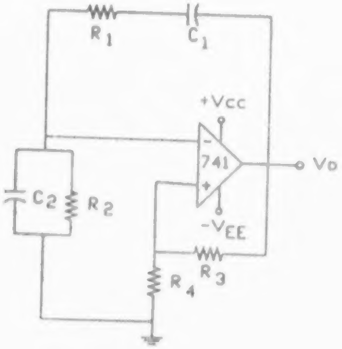

R1
C1
+Vcc
741
Vo
C2
R2
-VEE
R3
R4

Figure D 7.3-4

INFORMATION SHEET D 7.3 CONT'D.

The design of a Wein-bridge oscillator Figure D 7.3-2 is approached by determining the current level for each arm of the bridge. This value must be greater than the input bias current to the operational amplifier. Let's design the oscillator so that it has an output frequency of 10kHz using a 741 operational amplifier with a +/-10V power source.

From the 741's data sheet the maximum input current is 500mA. Keeping the branch currents large, let the branch current through R_4 equal 500μA, a thousand times larger. With a +/-10V supply, the output voltage of a 741 will be approximately +/-9V.

Thus

$$\begin{aligned} R_3 + R_4 &= 9\text{V}/500\mu\text{A} \\ &= 18\text{k ohms.} \end{aligned}$$

Because

$$R_3 = 2R_4, \ (R_3 + R_4) = eR_4 = 18\text{k ohms,}$$

therefore

$$R_4 = 18\text{k}\Omega/3 = 6\text{k ohms (5.6k ohm standard value)}$$

$$R_3 = 2R_4 = 2 \text{ X } 5.6\text{k} = 11.2\text{k}\Omega \text{ (12k ohm standard value).}$$

Because A_V must be greater than 3, R_3 must be greater than twice R_4. Let

$$R_2 = R_4 = 5.6\text{k ohms}$$

and

$$R_1 = r_2 = R = 5.6\text{k ohms.}$$

For the capacitors,

$$C = 1/2\pi fR$$

$$\begin{aligned} C_1 = C_2 = C &= 1\backslash(2\pi \text{ X } 10 \text{ kHz X } 5.6\text{k}\Omega) \\ &= 2840 \text{ pF} \\ &= 2700 \text{ pF (standard value).} \end{aligned}$$

ACTIVITY SHEET

D 7.4

OPERATIONAL AMPLIFIER OSCILLATORS

1. Define: feedback, positive feedback, negative feedback, regenerative feedback, degenerative feedback, feedback loop, tank circuit.
2. Explain the operation of the Wein-bridge operational amplifier oscillator.
3. Explain the operation of the Colpitts operational amplifier oscillator.
4. Design a 1kHz Wein-bridge oscillator using the 741 operational amplifier.
5. Construct the above circuit and verify its operation.

ACTIVITY SHEET 7.4

ANSWER SHEET

1. Feedback - output signal sent back into the circuit.

   Positive feedback - feedback signal is in phase with the input signal.

   Negative feedback - feedback signal is out of phase with the input signal.

   Regenerative feedback - positive feedback.

   Degenerative feedback - negative feedback.

   Feedback loop - components between output and input of oscillator.

   Tank circuit - RCL resonant circuit.

2. Operational amplifier is used as amplifier in with RC feedback loop.

3. Operational amplifier is used as amplifier in with lC feedback loop.

4. From the 741's data sheet the maximum input current is 500μA. Keeping the branch currents large, let the branch current through R_4 equal 500μA, a thousand time larger. With a +/-12V supply, the output voltage of a 741 will be approximately +/-11V.

   Thus

   $$R_3 + R_4 = 11\text{V}/500\mu\text{A} = 22\text{k ohms.}$$

   Because

   $$R_3 = 2R_4\ (R_3 + R_4) + 3R_4 = 22\text{k ohms}$$

   therefore

   $$R_4 = 22\text{k}\Omega/3 = 7.3\text{k ohms (6.8k ohm standard value)}$$

   $$R_3 = 2R_4 = 2 \times 6.8\text{k}\Omega = 13.6\text{k}\Omega\text{(15k ohm standard value).}$$

   Because A_v must be greater than 3, R_3 must be greater than twice R_4. Let

   $$R_2 = R_4 = 6.8\text{k ohms}$$

ACTIVITY SHEET D 7.4 CONT'D.

and

$$R_1 = R_2 = R = 6.8\text{k ohms.}$$

For the capacitors,

$$C = 1/2\pi fR.$$

5. Verify the construction of the oscillator by measuring its outputs. See text for specific values.

PROGRAM: ELECTRONICS

TASK: SOLID STATE OSCILLATORS

TASK #: D 7.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ____________

TERMINAL PERFORMANCE OBJECTIVE:

USING A SCHEMATIC, ANALYZE, CONSTRUCT AND TROUBLESHOOT SOLID STATE OSCILLATORS.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 5 out of 6 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 5 out of 6 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

SOLID STATE OSCILLATORS

D 7.5

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the required equipment used?	Y N
*2.	Was the required data recorded?	Y N
3.	Was the equipment used according to specifications?	Y N
*4.	Were all safety precautions followed?	Y N
5.	Was equipment returned to the proper storage area?	Y N
*6.	Was the experiment summarized properly?	Y N

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

962

SOLID STATE OSCILLATORS

EXAM

D 7.6

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Solid State Oscillators. Write the word that correctly completes each incomplete statement in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 9 out of 11 items correctly, 80%.

SOLID STATE OSCILLATORS

EXAM

D 7.6

1. The Hartley oscillator uses a tapped ___________ to provide a portion of the phase shift.

2. The Clapp oscillator adds a ____________ to the inductor branch of the Colpitts oscillator to increase the circuit stability.

3. When a quartz crystal is vibrating, it appears as a ________ circuit.

4. The advantage of a crystal oscillator resonant circuit is that it has a very high ___________.

5. It is necessary to provide ______________ feedback to generate oscillation in the amplifier circuit.

6. In the phase-shift oscillator the phase shift is provided by a series of __________ lead networks.

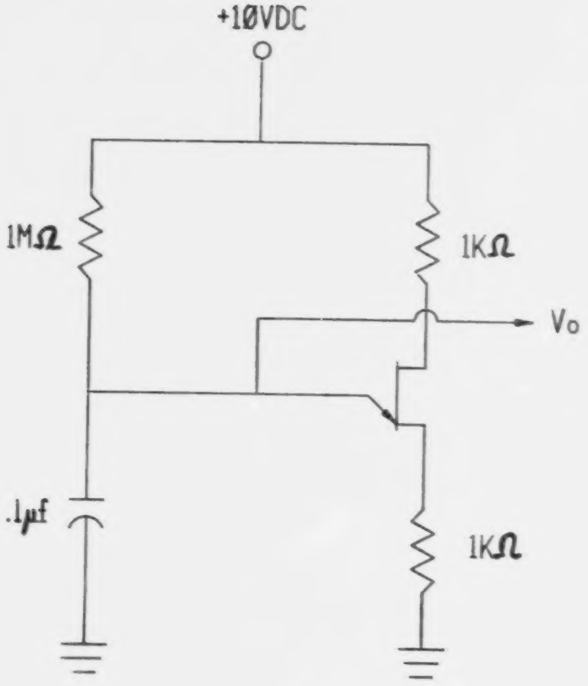
7. The Colpitts oscillator relies on a ____________ tap rather than an inductive tap.

8. The frequency of a relaxation oscillator is determined by the ____________ time constant.

9. The relaxation oscillator circuit uses a _________________ transistor.

10. The output of a relaxation oscillator is a ________________ waveform.

11. What is the operating frequency of the oscillator shown below?


+10VDC
1MΩ
1KΩ
Vo
.1μf
1KΩ

EXAM D 7.6

ANSWER KEY

1. inductor
2. capacitor
3. resonant
4. Q
5. positive
6. three
7. capacitive
8. RC
9. unijunction
10. sawtooth
11. 10 Hz

ELECTRONICS

ANALYZING ANALOG CIRCUITS

D 8: PULSE CIRCUITS

TASK:	Using a schematic, analyze, construct and troubleshoot basic pulse circuits.
PURPOSE:	Many areas of electronics, including digital and microprocessor, require the development and handling of pulses of electricity. This learning guide will explain the terms and processes necessary to assist in the understanding of these circuits.
OBJECTIVE:	Given a written examination you will analyze basic pulse circuits.

ESTIMATED CLASS TIME: 10 HOURS

PULSE CIRCUITS

LEARNING STEPS

D 8

READ: Information Sheet D 8.1, "Pulse Circuits."

READ: Information on pulse circuits in one or more of the references.

COMPLETE: Activity Sheet D 8.2, "Pulse Circuits."

REVIEW: Information Sheet D 8.1 and Activity sheet D 8.2.

COMPLETE: Laboratory performance on pulse circuits. Contact your instructor.

READ: Information Sheet D 8.3, "Pulse Circuit Design."

READ: Information on pulse circuits design in one or more of the references.

COMPLETE: Activity Sheet D 8.4, "Pulse Circuit Design."

REVIEW: Information Sheet D 8.3 and Activity Sheet D 8.4.

COMPLETE: Laboratory performance on pulse circuit design. Contact your instructor.

COMPLETE: Performance checklist D 8.5.

COMPLETE: Written examination D 8.6 for mastery of this task.

PULSE CIRCUITS

RESOURCES

D 8

1. ELECTRONIC PRINCIPLES, 3rd Edition, by Malvino (McGraw-Hill, 1984).
2. ELECTRONIC TROUBLESHOOTING, by Oleksy (Bobbs-Merrill-1983).
3. ELECTRONICS IN INDUSTRY, 5th Edition, by Chute & Chute (McGraw-Hill, 1979).
4. ESSENTIALS OF SOLID STATE ELECTRONICS, by Faber (Wiley, 1985).
5. PULSE FUNDAMENTALS IN SMALL SCALE DIGITAL CIRCUITS by Baumgartner (Reston, 1985).
6. SEMICONDUCTOR TECHNOLOGY, by Weedon (Energy Concepts, Inc., 1985).
7. SOLID-STATE ELECTRONICS, 2nd Edition, by Rutkowski (Bobbs-Merrill, 1983).
8. Any appropriate electronics textbook

REQUIRED EQUIPMENT

0 - 25 VDC @ 1A Power Supply
0 - 40 VAC @ 1A Isolated Power Supply
0 - 1IMHZ Function Generator
10 MHZ Dual Trace Oscilloscope
Digital Multimeter

INFORMATION SHEET

D 8.1

PULSE CIRCUITS

A basic pulse is a step waveform. This means that the voltage changes abruptly from one level to another level and back again. A pulse requires a number of unique measurements involving time and magnitude: rise time, pulse width, duty cycle, fall time, overshoot, undershoot, and pulse repetition rate. Figure D 8.1-1 shows an ideal rectangular pulse. It has positive and negative edges that are vertical and the top is flat.

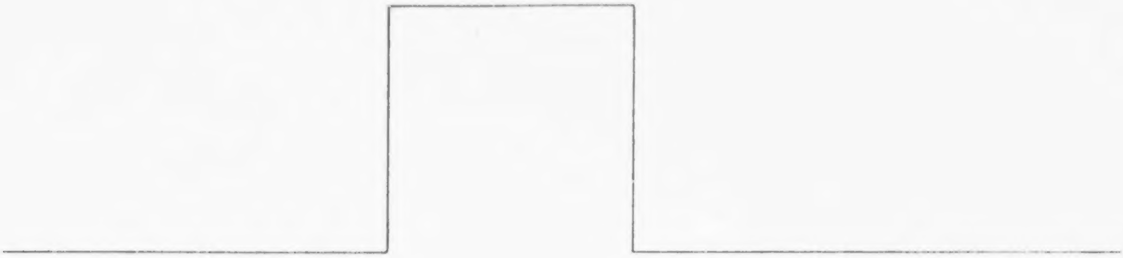


Figure D 8.1-1

Pulses may be either periodic or aperiodic. Pulses observed on an oscilloscope that repeat themselves at regular intervals are periodic. Square waves are examples of symmetrical periodic pulses. However, most pulses are not symmetrical, and often it is necessary to determine the pulse repetition time (PRT) and the pulse repetition frequency (PRF). The time from the start of one pulse to the start of the next pulse is the pulse repetition time. The pulse repetition frequency is the reciprocal of the pulse repetition time.

PRF = 1/PRT

Pulses occurring at random are called aperiodic pulses. The waveform in Figure D 8.1-2 shows an aperiodic waveform.

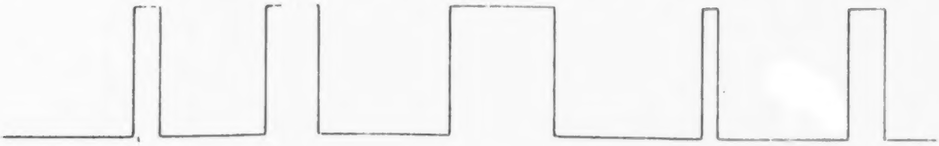


Figure D 8.1-2

970

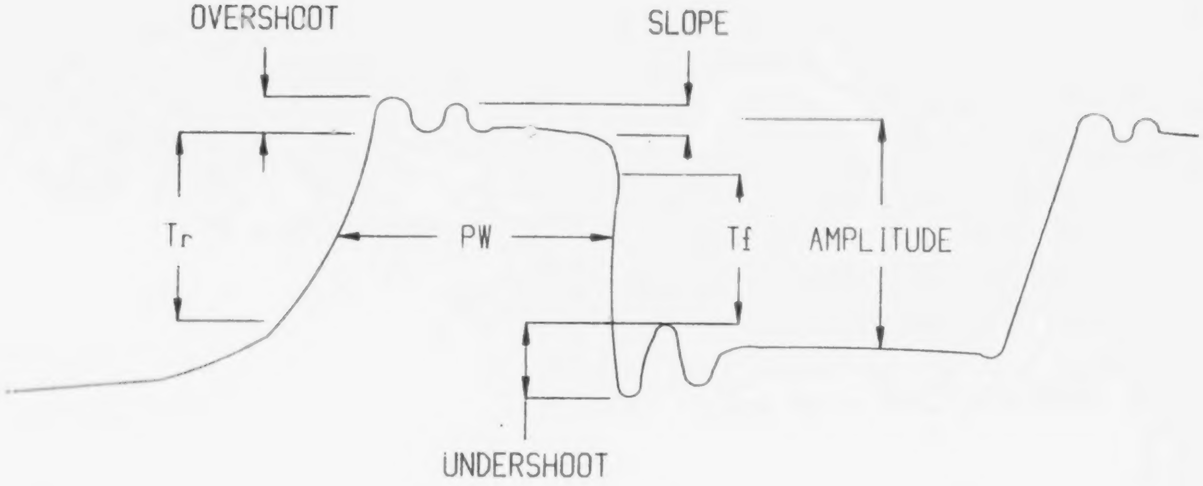


Figure D 8.1-3

Figure D 8.1-3 represents a portion of a typical pulse waveform. Indicated are the rise time, fall time, overshoot, undershoot, pulse width, slope, and amplitude.

The shape of a pulse can be changed by passing it through pulse shaping networks consisting of RC and/or RL components. Figure D 8.1-4 illustrates the effects of applying a pulse to accompanying RC circuit first with a long, medium, then short time constant.

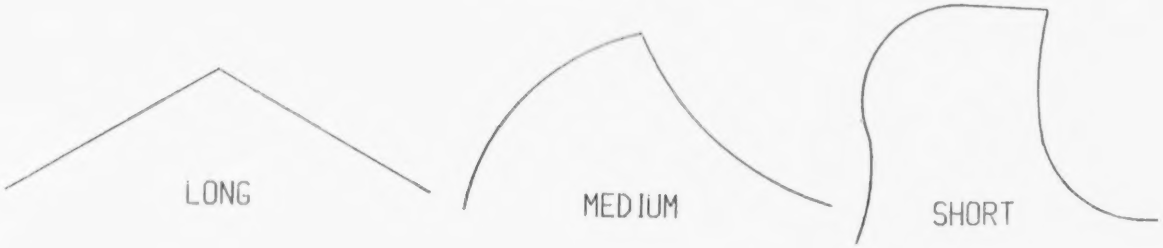


Figure D 8.1-4

To properly study pulses and pulse circuits, it is necessary to study the circuits used to generate pulses. Most popular types of circuits used to generate pulses use the 555 integrated circuit.

The 555 IC timer is a very popular device. The functional diagram shown in Figure D 8.1-5 contains five basic circuits, two comparators, a bistable flip-flop, a voltage divider, a discharge circuit, and an output stage. There are three equal value resistors constructing a voltage divider. The voltage divider provides a reference at two-thirds of the supply voltage to the threshold comparator. The trigger comparator is connected to the voltage divider referenced at one-third of the supply voltage. The output of the comparators is connected to the bistable flip-flop.

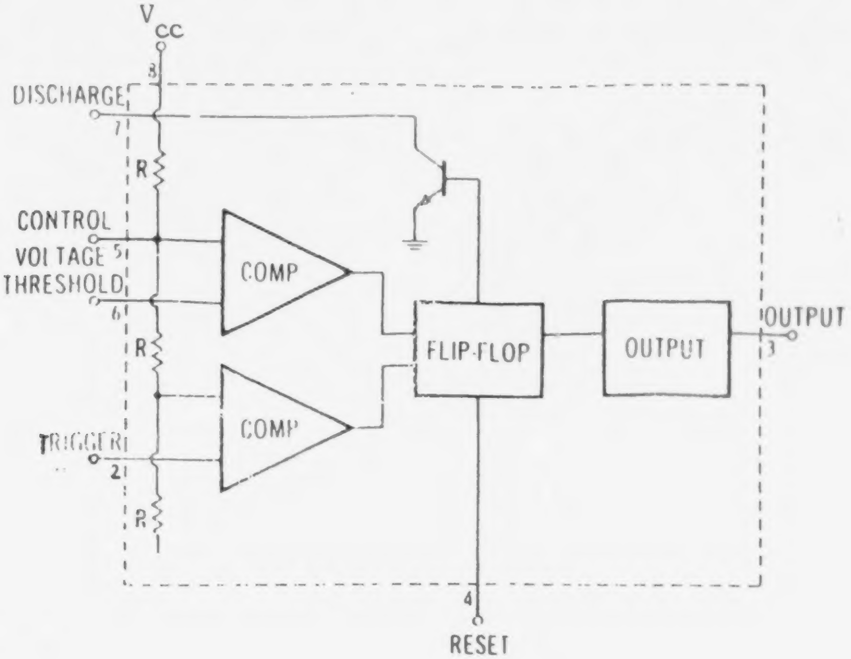


Figure D 8.1-5

A trigger voltage is applied to the trigger comparator. When this voltage drops below the referenced one-third supply voltage, the comparator changes state and the flip-flop drives its output high. The threshold input compares the voltage on the external RC timing network. When the RC voltage exceeds the two-thirds supply voltage, the threshold comparator rests the flip-flop. The flip-flop drives the output to its low state. The discharge transistor is turned on and the external timing RC network is discharged. As soon as the capacitor is discharged, the circuit resets and waits to be retriggered. A trigger pulse restarts the sequence.

Figure D 8.1-6 shows the operation of a 555 as a pulse generator. The threshold and trigger inputs are tied together and connected to the external timing capacitor. External resistors are connected to the supply voltage and form an RC time constant with the capacitor. The discharge circuit is connected to the junction of the two resistors. The threshold and trigger connections are made between the junction of the second resistor and the capacitor. The application of power to the circuit causes the capacitor to charge from the supply voltage through the resistors. The capacitor charge reaches the threshold level of two-thirds of the supply. The output goes low and the voltage on the capacitor discharges through resistor RB and the discharge transistor of the timer. When the capacitor voltage decreases to one-third of the supply voltage, the flip-flop is reset and a new charging cycle to start. The capacitor voltage varies from one-third to two-thirds of the supply voltage. The output is equal to the supply voltage during the charging period, and at ground during the discharge period.

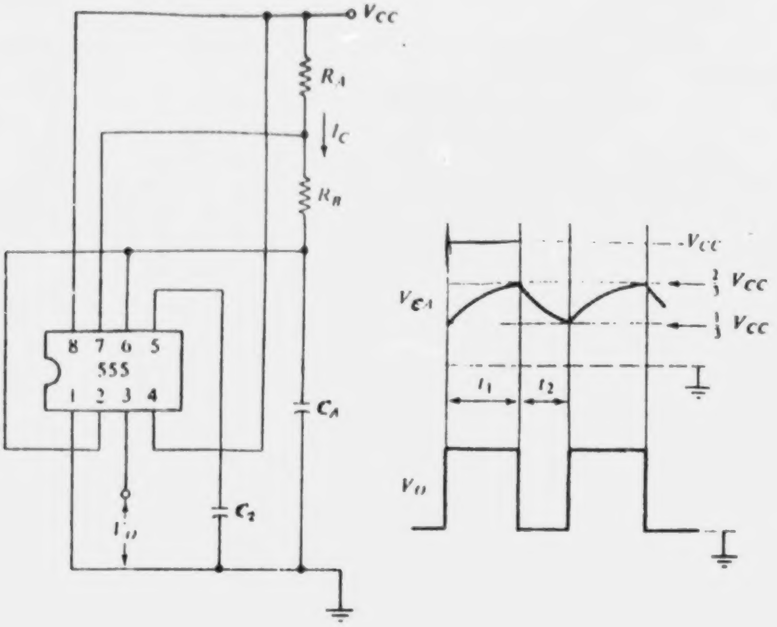


Figure D8.1-6

The frequency of the pulse generator is determined as:

$$f = \frac{1.46}{(RA + 2RB)C}$$

when RA, RB, and C are connected as shown in Figure D8.1-7.

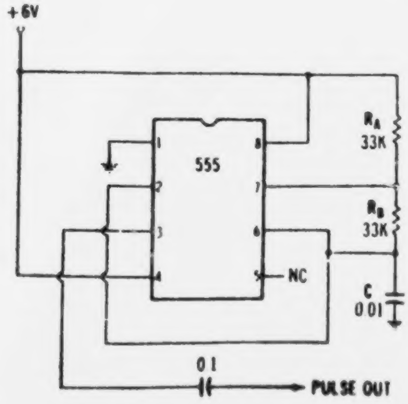
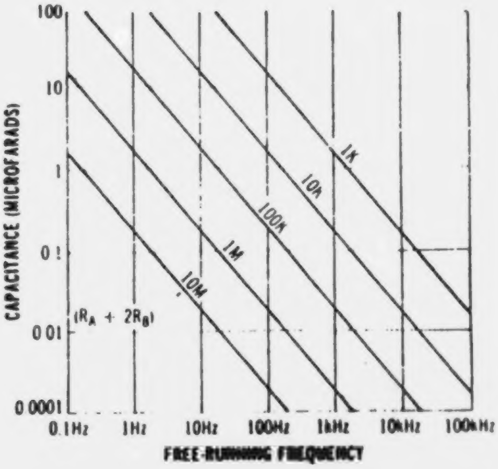


Figure D8.1-7

The graph in Figure D 8.1-8 represents the values of capacitance and resistance in relation to the operating frequency of the circuit shown.



FigureD 8.1-8

The actual equation for determining the duty cycle of the circuit is:

$$D = \frac{RB}{RA + 2RB}$$

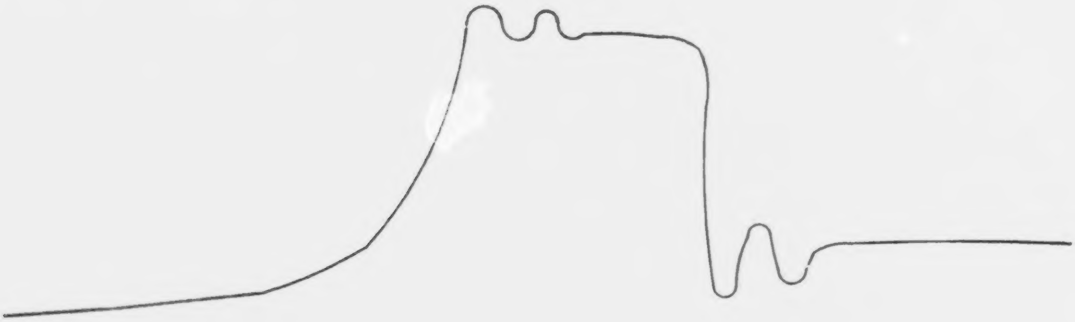
Notice that the capacitor value has no effect on the duty cycle. Therefore the frequency of the circuit can be changed by adjusting the value of the capacitor without effecting the duty cycle.

ACTIVITY SHEET

D 8.2

PULSE CIRCUITS

1. Label the waveform below for the following: rise time, fall time, tilt, overshoot, ringing, amplitude, and pulse width.



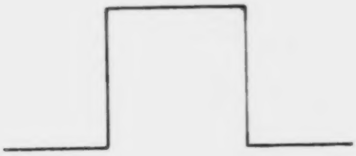
2. Explain the basic construction of the 555 integrated circuit.

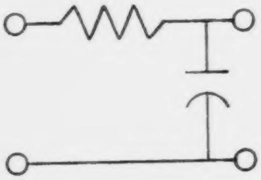
3. Explain how to determine the duty cycle of the 555 operating as a pulse generator.

4. Explain why the 555 above can not achieve a 50% duty cycle.

5. What effect does changing supply voltage have on the timing accuracy of the 555? Explain.

6. Using the waveform below, draw the expected output waveform after passing through circuit with a short, medium, and long time constant.





ACTIVITY SHEET D 8.2

ANSWER SHEET

1. See Text

2. Contains two comparators, flip-flop, voltage divider, output amplifier

3. $D = RB/(RA + 2RB)$

4. In the above equation RA can never be zero

5. Very little. Because reference voltages are produced within the 555 using its internal voltage divider.

INFORMATION SHEET

D 8.3

PULSE CIRCUIT DESIGN

One method used to generate a pulse is the monostable multivibrator. This device is available as an integrated circuit. Figure D 8.3-1 shows the 74121 TTL compatible multivibrator. The device operates from a single, five-volt power supply and provides two complementary outputs (Q and not Q). There are three input terminals. Two of the inputs, A_1 and A_2 typically require -1.4V to effect triggering. Input B triggers the circuit when a level greater than approximately +1.55V is applied.

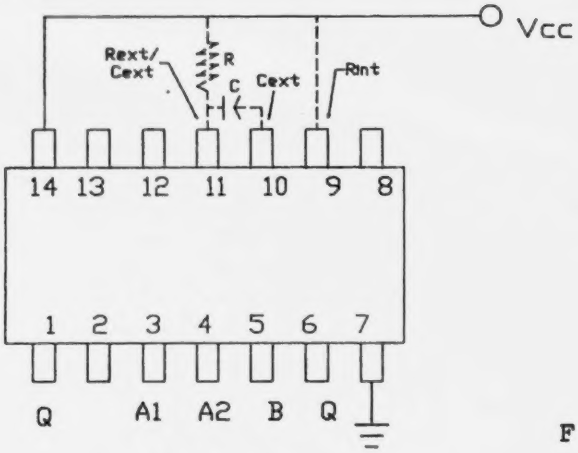


Figure D8.3-1

The output pulse duration from this device lasts 30 to 35 nanoseconds when no external components are employed and R_{int} (pin 9) is connected directly to V_{CC}. For longer pulse durations, R_{int} is left unconnected and a RC network constructed and connected to pins 10 and 11 as shown in the figure above. This range of values for the external capacitor is 0 to 1000µF. The resistor value may range from 1.4k to 40k ohms.

With this range of values, the maximum pulse width can be:

$$PW = 0.7(40k\Omega)(1000\mu F)$$

$$= 28 \text{ seconds}$$

Thus this small 14 pin integrated circuit package, when triggered, can generate a fixed pulse with a duration from a minimum of 30 nanoseconds to a maximum of 28 seconds.

Often it is necessary to generate more than a single pulse, such as in the generation of a square wave. The circuit that accomplishes this is called an astable multivibrator. There are many different methods that may be used to construct an astable multivibrator. Figure D 8.3-2 shows an operational amplifier configured to produce a square wave. You may recognize that the circuit appears very similar to the inverting Schmitt trigger. The circuit is a Schmitt trigger with an additional resistor and capacitor added to the circuit, R_3 and C_1.

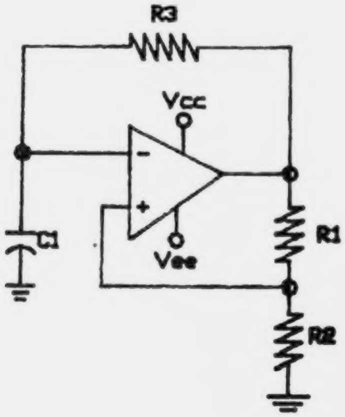


Figure D 8.3-2

Capacitor C_1 and resistors R_1 and R_2 are the reference voltages for the amplifier. The capacitor charges through R_3. When the voltage across the capacitor and the voltage from the center of the R_1-R_2 voltage divider are equal, the output of the amplifier will start towards zero. When this happens, the voltage divider voltage decreases. It is now less than the value of the capacitor, and the output of the op amp drives into saturation on the other side of the power supply. The capacitor is now being discharged and recharged through R_3. When the capacitor's charge is again equal to the voltage divider's voltage, the process cycles again and continues, generating a square wave.

Let's use a 741 operational amplifier and design an astable multivibrator with an output frequency of 300Hz with an amplitude of +/-8V. The 741's output can only swing to within approximately one volt of the power supply. To get a +/-8V output, the circuit will have to be supplied +/-9V. To get a symmetrical waveform, let the Schmitt trigger voltages equal one-half of the output voltage or:

$$V_{R2} = 8V/2$$

$$= 4V$$

To overcome the input bias current of the operation amplifier, (which from the data sheet is 500nA) make the charging and output currents 100 times larger.

$$I_{R3} = 100 \text{ X } 500\text{na}$$
$$= 50\mu\text{A}$$

The value of R_2v then can be determined using Ohm's law.

$R_2 = V_{R_2}/I_{R_2}$

$= 4.0\text{V}/50\mu\text{A}$

$= 80\text{k}$ ohms (use 82k as the closest standard value)

Because the waveform is to be symmetrical

$R_1 = R_2$

The charging voltage for the capacitor can be determined by subtracting the trigger voltage from the output voltage.

$V_{R_1} = V_O - V_{\text{trigger}}$

$= 8\text{V} - 4\text{V}$

$= 4\text{V}$

The value of R_3 then can be determined using Ohm's law.

[illegible] $= V_{R_3}/I_{R_3}$

$= 4.0\text{V}/50\mu\text{A}$

$= 80\text{k}$ ohms (use 82k as the closest standard value)

Because we chose to have an operating frequency of 300Hz the charging time available for the capacitor is one half of the period of the waveform. The period (T) is

$T = 1/300\text{Hz}$

$= 3.3\text{mS}$

one half of this is

$t = 3.3\text{mS}/1.67$

The capacitor size is determined as

$$C = \frac{t}{R_3 I_n \dfrac{E - E_o}{E - E_c}}$$

$$= \frac{1.67\text{mS}}{82\text{k } I_n \dfrac{8 - (-4)}{8 - 4}}$$

$= 0.0186\mu\text{F}$ Use $0.02\mu\text{F}$ as the closest standard value.

ACTIVITY SHEET

D 8.4

PULSE CIRCUIT DESIGN

The following circuits to be connected are from Electronic Principles, 3rd Edition, by Malvino. If text is not available, use a text which includes the operation of a 741 operational amplifier.

1. Design a monostable multivibrator using the 74121 that produces a 100mS pulse when triggered by a 3V pulse.
2. Construct and verify the operation of the above circuit.
3. Design an astable multivibrator using the 741 operational amplifier that produces a +/-10V 1kHz waveform.
4. Construct and verify the operation of the above circuit.

ACTIVITY SHEET D 8.4

ANSWER SHEET

1. Any values within the stated limits (see text) of R and C may be used that result in -- .7RC being equal to 100mS.
2. Should function within tolerance of components.
3. Circuit dependent.
4. Should function within tolerance of components.

PROGRAM: ELECTRONICS

TASK: PULSE CIRCUITS

TASK #: D 8.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ____________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

USING A SCHEMATIC, ANALYZE, CONSTRUCT AND TROUBLESHOOT BASIC PULSE CIRCUITS.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 5 out of 6 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 5 out of 6 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

PULSE CIRCUITS

D 8.5

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the required equipment used?	Y N
*2.	Was the required data recorded?	Y N
3.	Was the equipment used according to specifications?	Y N
*4.	Were all safety precautions followed?	Y N
5.	Was equipment returned to the proper storage area?	Y N
*6.	Was the experiment summarized properly?	Y N

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

DIRECT-COUPLED AMPLIFIERS

EXAM

D 8.6

DIRECTIONS:

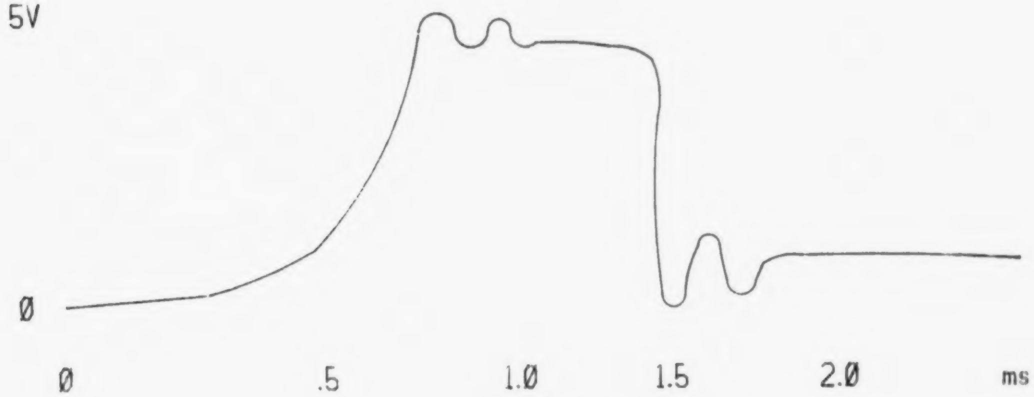
The purpose of this exam is to determine whether or not you have understood the information on Pulse Circuits. Write the information required in the numbered blank spaces on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 4 out of 5 items correctly, 80%).

EXAM

D 8.6

PULSE CIRCUIT DESIGN

1. Label the waveform below for the following: rise time, fall time, slope or tilt, overshoot, ringing, amplitude, and pulse width.



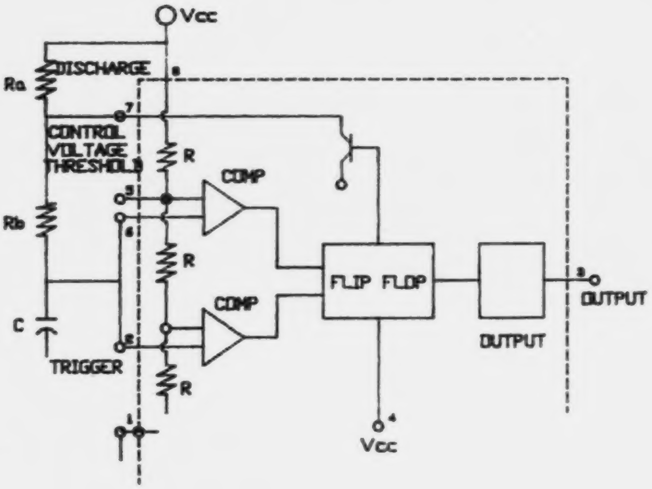
2. Using the waveform above, determine the following: rise time, fall time, tilt, overshoot, amplitude, and pulse width.

3. Determine the duty cycle of the 555, shown below, operating as a pulse generator.

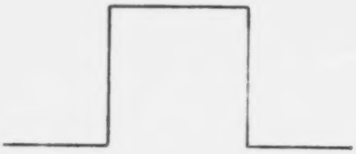
$R_A = 10\ k\Omega$

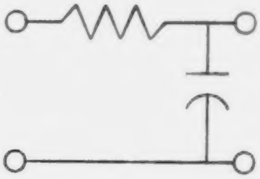
$R_B = 22\ k\Omega$

$C = .01\ \mu f$


Vcc
Ra
DISCHARGE
8
7
CONTROL
VOLTAGE
THRESHOLD
R
COMP
5
6
Rb
R
FLIP FLOP
3
OUTPUT
COMP
C
2
OUTPUT
TRIGGER
R
1
4
Vcc

4. Using the waveform below, draw the expected output waveform after passing it through the circuit with a short, medium, and long time constant.





5. The external resistance and capacitance connected to a 74121 are 10k ohms and 1µF. What will be the pulse width for the circuit?

EXAM D 8.6

ANSWER SHEET

1. See Figure D 8.1-3.

2. $t_r = .05\ m^5$

   $t_f = .05\ m^5$

   $t_{ilt} = 10\%$

   $O_s = .5V$

   $A = 5V$

   $PW = 1\ ms$

3. $2700\ Hz = \frac{1.46}{(10K + 2(z2k))\ .01}$

4. See Figure D 8.1-4.

5. 7mS

ELECTRONICS

ANALYZING ANALOG CIRCUITS

D 9: MODULATION CIRCUITS

TASK: Using a schematic, analyze, construct and troubleshoot modulation circuits.

PURPOSE: The area of electronics called communications uses electrical energy to transmit data from one point to another. Many of these processes require modulation circuits. This learning guide will explain the terms and processes necessary to assist in the understanding of these applications.

OBJECTIVE: Given a written exam you will analyze modulation circuits.

ESTIMATED CLASS TIME: 10 HOURS

MODULATION CIRCUITS

LEARNING STEPS

D 9

READ: Information Sheet D 9.1, "Single-Stage Amplifiers."

READ: Information on modulation circuits from the following resources.

COMPLETE: Activity Sheet D 9.2, "Single-Stage Amplifiers."

REVIEW: Information Sheet D 9.1 and Activity Sheet D 9.2.

COMPLETE: Laboratory performance on modulation circuits. Contact your instructor.

READ: Information Sheet D 9.3, "Pulse Modulation."

READ: Information on pulse modulation in one or more of the references.

COMPLETE: Activity Sheet D 9.4, "Pulse Modulation."

REVIEW: Information Sheet D 9.3 and Activity Sheet D 9.4.

COMPLETE: Laboratory performance on pulse modulation. Contact your instructor.

COMPLETE: Performance Checklist D 9.5.

COMPLETE: Written Exam D 9.6 for mastery of this task.

MODULATION CIRCUITS

RESOURCES

D 9

1. ELECTRONIC COMMUNICATIONS (Heath Company, 1984).
2. ELECTRONIC PRINCIPLES, 3rd Edition, by Malvino (McGraw-Hill, 1984).
3. ELECTRONIC TROUBLESHOOTING, by Oleksy (Bobbs-Merrill-1983).
4. ELECTRONICS IN INDUSTRY, 5th Edition, by Chute & Chute (McGraw-Hill, 1979).
5. ESSENTIALS OF SOLID STATE ELECTRONICS, by Faber (Wiley, 1985).
6. PULSE FUNDAMENTALS IN SMALL SCALE DIGITAL CIRCUITS by Baumgartner (Reston, 1985).
7. SEMICONDUCTOR TECHNOLOGY, by Weedon (Energy Concepts, Inc., 1985).
8. SOLID-STATE ELECTRONICS, 2nd Edition, by Rutkowski (Bobbs-Merrill, 1983).
9. Any appropriate electronics textbook

REQUIRED EQUIPMENT

0 - 25 VDC @ 1A Power Supply
0 - 40 VAC @ 1A Isolated Power Supply
0 - 1IMHZ Function Generator
10 MHZ Dual Trace Oscilloscope
Digital Multimeter

INFORMATION SHEET

D 9.1

AMPLITUDE AND FREQUENCY MODULATION

There are two basic types of modulation circuits: amplitude modulation (AM), and frequency modulation (FM). Amplitude modulation takes a constant frequency signal (called a carrier) and varies its amplitude to correspond with the amplitude of the modulating signal. To obtain amplitude modulation, the audio signal and the carrier must be combined in a stage called the modulator. This circuit is used in AM transmitters and signal generators. A signal generator produces a low-level AM signal for testing and alignment purposes.

The circuit in Figure D 9.1-1 is the schematic diagram of a diode modulator. The carrier and audio are both applied to the circuit as shown. This produces the resulting waveforms as indicated. The purpose of the tank circuit, which is tuned to the carrier frequency, is to produce the negative half-cycles for each input pulse. The diode is an example of nonlinear mixing.

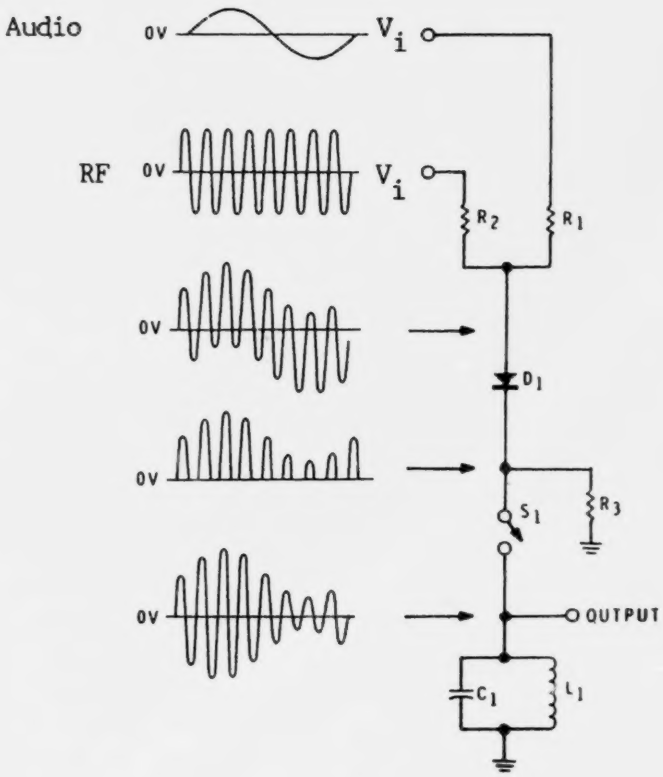


Figure D 9.1-1

A more common form of amplitude modulation is collector modulation. This is called plate modulation in vacuum tube in modulators. In the collector modulation circuit shown in Figure D 9.1-2 the modulating signal is applied to the transistor's collector in series with the DC supply voltage. This is accomplished by the transformer connected in series between the RF choke and V_{CC}. The output of the transistor is developed across the RF choke. This is capacitively coupled to the tank circuit consisting of the two capacitors and one inductor. The function of the tank circuit is the same as in the diode modulator.

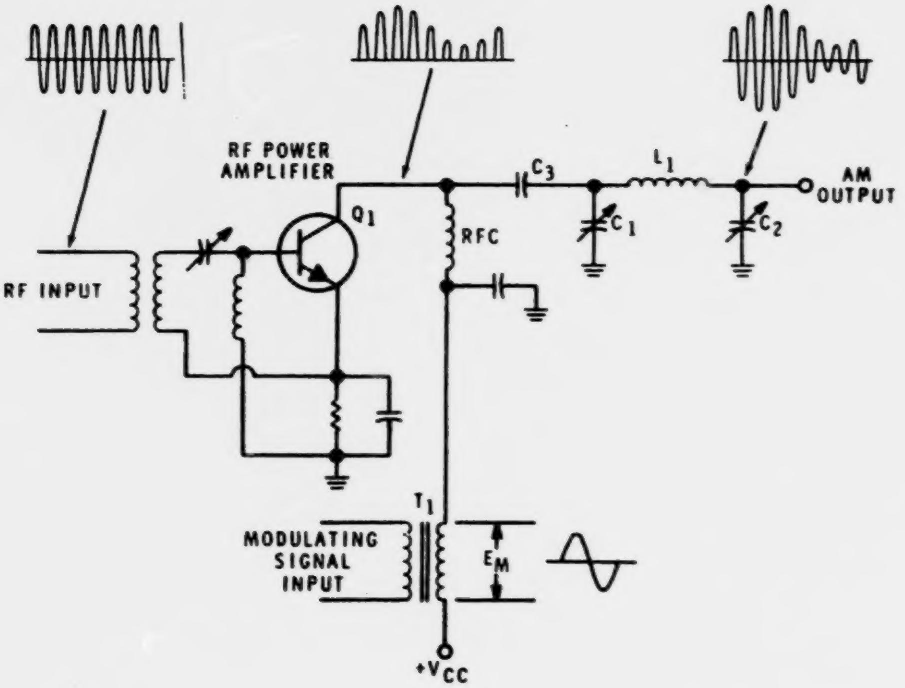


Figure D 9.1-2

This circuit is unable to achieve 100% modulation because the transistor saturates before reaching maximum modulation. Also, the modulation transformer must be capable of carrying all of the output current; this makes the transformer very large and expensive.

INFORMATION SHEET D 9.1 CONT'D.

The circuit in Figure D 9.1-3 represents a progressive series modulator. This circuit greatly improves the efficiency of the modulation. The advantage of this circuit is that at carrier-only conditions (0% modulation) very little power is dissipated across the modulator. This modulator offers much better efficiency while maintaining direct coupling between the modulating signal and the RF oscillator. The disadvantage is the increased circuit complexity.

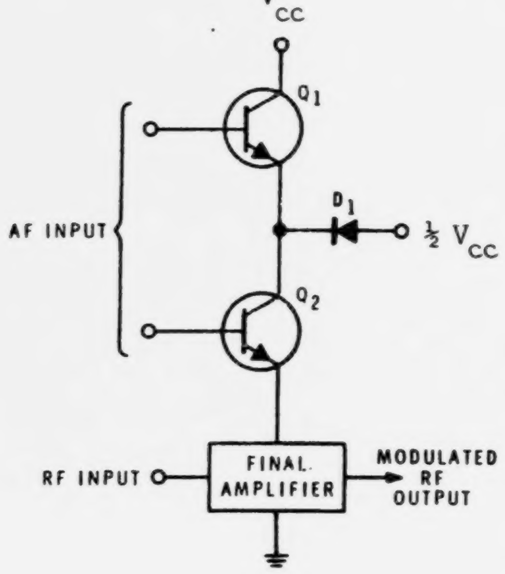


Figure D 9.1-3

There are additional AM techniques such as single sideband which are more efficient in the transmission of the signal, but the circuits are much more complex and expensive to build.

Frequency modulation takes the same carrier waveform as AM but varies the frequency of the carrier in relation to the audio signal. There are two types of modulation processes, direct and indirect. Direct modulation varies the master oscillator's frequency according to the modulating signal. Indirect modulation varies the carrier signal in a later stage of the transmitter.

The schematic in Figure D 9.1-4 represents a direct reactance modulation circuit. This means that the transistor is not only part of the RF oscillator, it is also acting like capacitance on the master oscillator tank circuit. When an audio signal is applied to the modulator, its reactance varies and thus the master oscillator's frequency. Also, bipolar transistor or vacuum tube could be used in place of the FET.

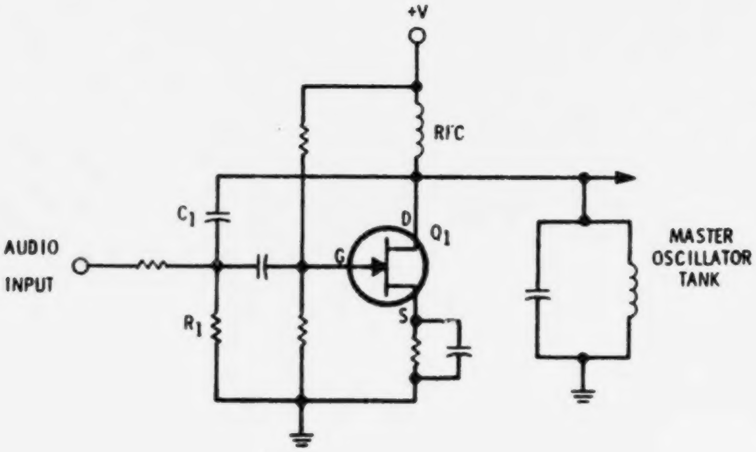


Figure D 9.1-4

INFORMATION SHEET D 9.1 CONT'D

The schematic, Figure D 9.1-5, illustrates indirect modulation using a phase modulator. The RF input signal is from the master oscillator. This input is applied to the circuit as shown. When an audio signal is applied to the transistor the gain of the stage varies. This changes the amplitude and the phase of the RF signal. To remove the AM the output of the circuit is usually fed into a class C amplifier. The advantage of a phase modulator is that the master oscillator is unaffected by the modulation signal.

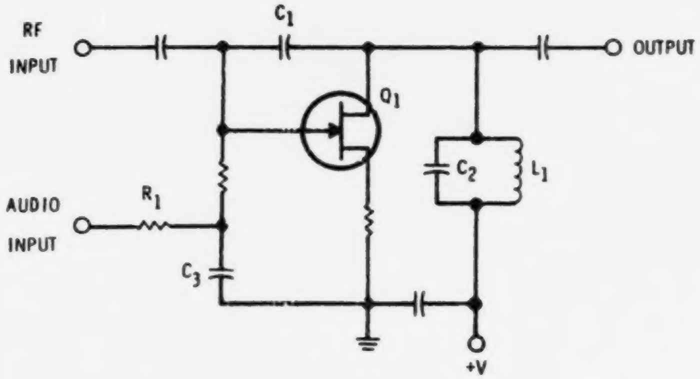


Figure D 9.1-5

ACTIVITY SHEET

D 9.2

AMPLITUDE AND FREQUENCY MODULATION

1. Name five methods of amplitude modulation.
2. Define modulator.
3. State two purposes of a π output network.
4. List the disadvantages of standard AM.
5. Name two types of angle modulation.
6. Construct and test a simple AM modulator circuit.
7. Construct and test a simple FM modulator circuit.

ACTIVITY SHEET D 9.2

ANSWER SHEET

1. Diode, collector or plate, progressive series, base or grid, emitter or cathode, balanced modulator.
2. Device used to mix audio signal with RF.
3. Impedance matching, harmonic rejection.
4. Highly susceptible to atmospheric interference.
   Carrier required - inefficient
5. Direct and Indirect
6. Hardware dependent
7. Hardware dependent

INFORMATION SHEET

D 9.3

PULSE MODULATION

The amplitude of an analog signal may be sampled at regular intervals and converted into pulses. The pulses are then processed, transmitted or recorded. Figure D 9.3-1 illustrates the processes for converting this signal into pulse amplitude modulation (PAM), pulse duration modulation (PDM), pulse position modulation (PPM), and pulse coded modulation (PCM).

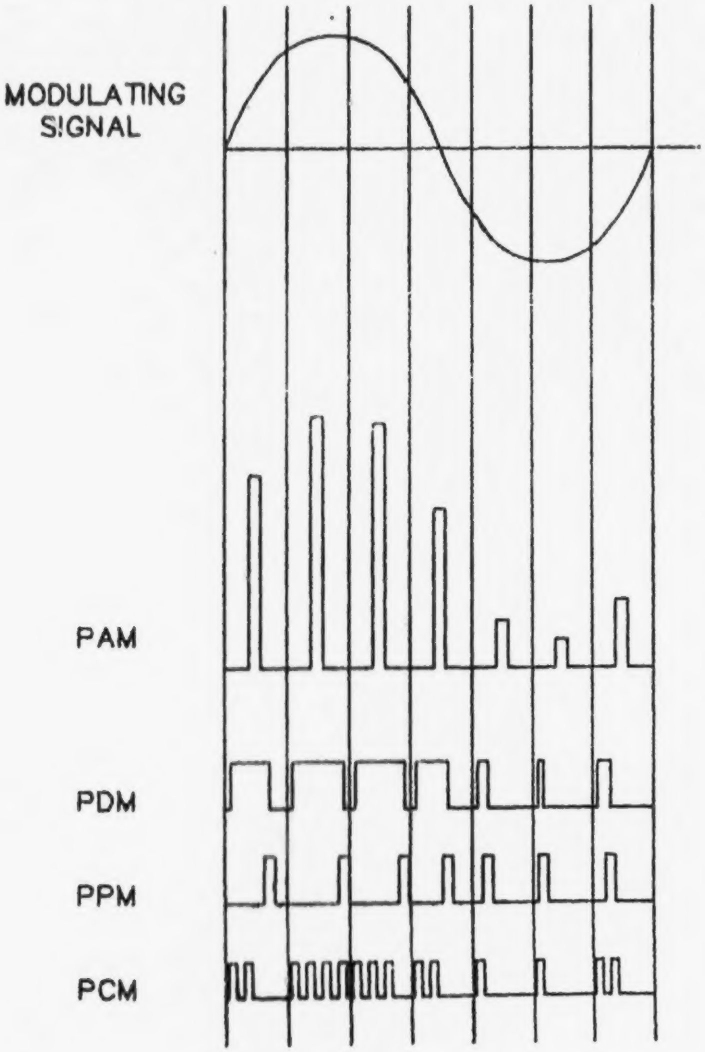


Figure D 9.3-1

PAM is the simplest type of pulse modulation. The amplitude of each pulse is proportional to the instantaneous amplitude of the modulating signal. The greater the amplitude of the modulating signal, the higher the pulse amplitude. The pulses may be very narrow and widely spaced, requiring low average power and resulting in high efficiency.

PDM or pulse width modulation pulses have a constant amplitude. The width of the pulses is proportional to the instantaneous amplitude of the modulating signal. The greater the amplitude of the modulating signal, the longer the pulse duration. This mode of modulation is more suitable for magnetic recording than is PAM.

PPM is more efficient than either PAM or PDM for radio transmission. All the pulses have the same amplitude and duration. The position of each pulse varies with the amplitude of the modulating signal. The greater the amplitude the more the pulse is displaced in its time frame to the right.

PCM is the most complicated type of pulse modulation. However, it is possible for PCM to be the most efficient and accurate of these methods. The amplitude of the modulating signal is converted into a binary number. The greater the amplitude, the larger the binary number. This type of modulation is used in digital audio disk technology.

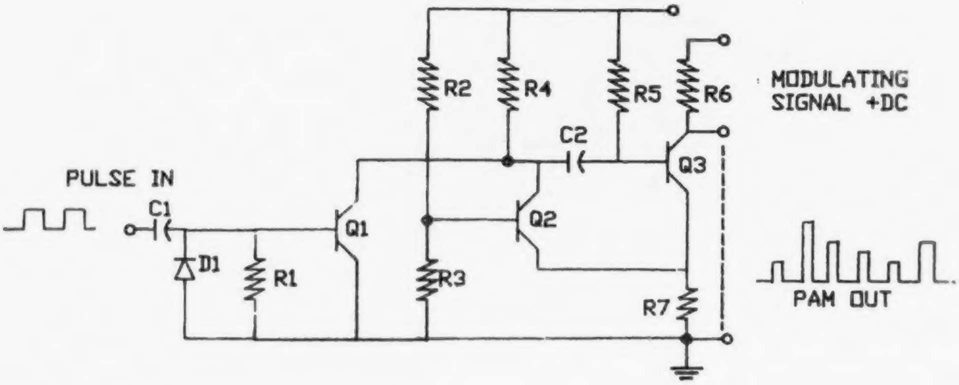


Figure D 9.3-2

INFORMATION SHEET D 9.3 CONT'D.

Figure D 9.3-2 shows the construction of a simple PAM modulator. The pulse input provides the sampling rate. Each pulse triggers the monostable multivibrator. The fixed duration output from the monostable multivibrator is used to turn on transmitter Q3. This allows the amplitude of the modulating signal, which has been converted to a varying positive DC voltage, to be passed as the output as shown.

ACTIVITY SHEET

D 9.4

PULSE MODULATION

1. List the four types of pulse modulation.
2. List an advantage for each type of pulse modulation.
3. Explain the method of modulation for each type of modulation listed above.
4. Construct and test a typical pulse modulation circuit.

ACTIVITY SHEET D 9.4

ANSWER SHEET

1. PAM, PDM, PPM, PCM

2. PAM - Easy to implement
   PDM - Suited to magnet recording
   PPM - Efficient radio transmission
   PCM - Accuracy and efficiency

3. See Text.

4. Hardware dependent

PROGRAM: ELECTRONICS

TASK: MODULATION CIRCUITS

TASK #: D 9.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

USING A SCHEMATIC, ANALYZE, CONSTRUCT AND TROUBLESHOOT MODULATION CIRCUITS.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 5 out of 6 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 5 out of 6 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

MODULATION CIRCUITS

D 9.5

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the required equipment used?	Y N
*2.	Was the required data recorded?	Y N
3.	Was the equipment used according to specifications?	Y N
*4.	Were all safety precautions followed?	Y N
5.	Was equipment returned to the proper storage area?	Y N
*6.	Was the experiment summarized properly?	Y N

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

MODULATION CIRCUITS

EXAM

D 9.6

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Modulation Circuits. Write A or B (for True or False) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, 80%).

MODULATION CIRCUITS

EXAM

D 9.6

1. Modulation is the conversion of a transmitted signal back to the original frequencies by a receiver.

   A. True
   B. False

2. The modulated high frequency sine wave of a circuit is called the carrier.

   A. True
   B. False

3. The two basic types of modulation are amplitude and frequency.

   A. True
   B. False

4. The amplitude of the output waveform from an amplitude modulator is constant.

   A. True
   B. False

5. With amplitude modulation, the carrier's amplitude is varied in accordance with the modulating signal.

   A. True
   B. False

6. When a signal is amplitude modulated, two additional signals are produced called sidebands.

   A. True
   B. False

7. The shape of the modulation envelope of an AM signal is dependent on the sidebands of the signal.

   A. True
   B. False

EXAM D 9.6 CONT'D.

8. The amount of frequency change in an FM signal is called its frequency deviation, and changes equally above and below its center frequency.

   A. True
   B. False

9. The rate of carrier frequency deviation is determined by the amplitude of the modulating signal.

   A. True
   B. False

10. In FM, like AM, there are only two sidebands, upper and lower.

   A. True
   B. False

EXAM ANSWER SHEET

D 9.6

1. B
2. A
3. A
4. B
5. A
6. A
7. A
8. A
9. B
10. B

ELECTRONICS

ANALYZING DIGITAL ELECTRONIC CIRCUITS

E 1: LOGIC FAMILIES

TASK: Define digital and analog circuits, and differentiate between digital logic families.

PURPOSE: Integrated circuits (ICs) can generally be divided into two broad categories, linear and digital. The digital ICs can be further divided into logic families. After you complete this learning guide, you should be able to distinguish between analog and digital circuits and also logic families.

OBJECTIVE: Given a written examination, you will define digital and analog circuits, and differentiate digital logic families.

ESTIMATED CLASS TIME: 3 HOURS

LOGIC FAMILIES

LEARNING STEPS

E 1

READ: Information Sheet E 1.1, "Digital vs. Analog."

READ: Information on digital circuits from the following resource list.

COMPLETE: Activity Sheet E 1.2, "Digital vs. Analog."

READ: Information Sheet E 1.3, "Logic Families."

READ: Information on logic families from the following resource list.

COMPLETE: Activity Sheet E 1.4, "Logic Families."

REVIEW: All materials covered by this guide.

COMPLETE: Written Exam E 1.5. Contact your instructor.

LOGIC FAMILIES

RESOURCES

E 1

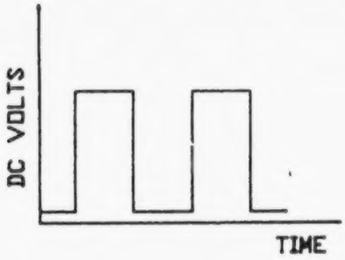
1. CMOS DATA MANUAL (Motorola).
2. Brey, DIGITAL ELECTRONICS (Bobbs-Merrill, 1984).
3. Tokheim, DIGITAL ELECTRONICS TEXT AND ACTIVITY MANUAL (McGraw-Hill, 1984).
4. Tocci, DIGITAL SYSTEMS (Prentice-Hall, 1984).
5. DIGITAL TECHNIQUES STUDENT WORKBOOK (Heath Co., 1981).
6. Williams, DIGITAL TECHNOLOGY (SRA, 1982). 2nd Ed.
7. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Ed.
8. Texas Instrument TTL DATA MANUAL.

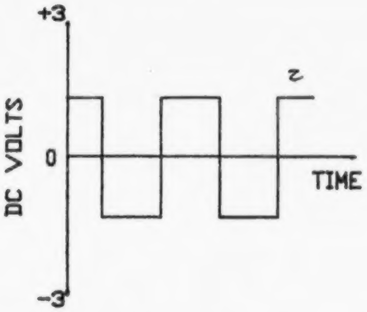
INFORMATION SHEET

E 1.1

DIGITAL VS. ANALOG

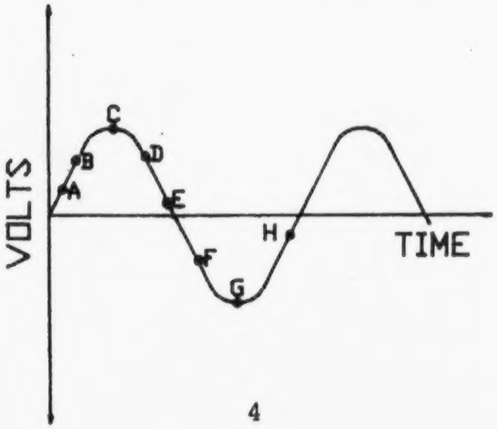
A digital circuit could be defined as a circuit which deals with electrical signals having only two distinct voltage levels. An example could be "light on/light off," positive voltage and ground, negative voltage/positive voltage, or current flowing/no current flowing. With a digital signal there is no "in between state." The circuit has two distinct levels. Shown below are some examples of digital signals.





Some examples of digital devices or circuits include square wave generator, calculator, digital clock, a pair of dice. Dice might appear to be a strange digital device, but they have no "in-between state;" that is, they do not land and stay on their edges. The die will land on one face and display a distinct number. The fact that a digital circuit has only two states makes it very useful when used in logic circuits or computer circuits. The digital circuits can be structured to "say" true/false, yes/no, or go/no-go.

By contrast an analog circuit is defined as a circuit in which output varies continuously. It does not have just two voltage levels. It is made of many voltage levels. An example of an analog signal is the sine wave. If you study the sine wave drawn below you can see that it is a graph of a voltage that varies with time and each point marked on the wave is a distinct voltage.



Some examples of analog circuits or devices include clock with hands, sine wave generator, V.O.M. with needle type movement, slide-rule, and audio amplifier.

In summary, a digital signal has two distinct states with no in-between points. It makes very quick transitions from one of its voltage points to the other. It yields a definite output, on/off, true/false, or 1:23:45. On the other hand, the analog signal has many points between maximum and minimum, it takes a period of time for this transition to occur, and finally its output is not always definite: it might be 23 1/2 minutes after or 24 minutes after one o'clock.

ACTIVITY SHEET

E 1.2

DIGITAL VS. ANALOG

Directions: Below is a list of signals and devices. Across from each is a blank. In that blank mark an "A" if the item is analog. Mark a "D" if the item is digital.

1. Sine Wave ____________
2. Square Wave ____________
3. Continuous ____________
4. Resistor Substitution Box ____________
5. Temperature ____________
6. Radio volume control ____________
7. Sand grains on a beach ____________

Score yourself by reviewing the answers to these items (answers on the next page). If you missed more than 2 of these items, you should re-read the information sheet on "analog vs. digital."

If you missed fewer than two, continue with the next learning step in this guide.

ACTIVITY SHEET E 1.2

ANSWER SHEET

1. A

2 D

3. A

4. D (Its output is discrete; there is one resistance).

5. A

6. A

7. D (These are discrete; they can be counted).

INFORMATION SHEET

E 1.3

LOGIC FAMILIES

Logic families are groups of digital integrated circuits (ICs) which operate at specific voltage or signal levels. Each family shares characteristics thus helping to determine which family should be used for a particular application. Each family also shares a common fabrication technology. Using integrated circuits by families makes the interconnecting of ICs (chips) very easy.

Resistor-transistor logic (RTL) was one of the earliest families to become commercially available in IC form. RTL is no longer used and is stocked only for replacement. Figure E 1.3-1 is an example of an RTL inverter. This family uses a monopolar power supply and operates from 3.6 volts to 4.0 volts. One advantage of RTL logic is that no combination of opens or shorts will destroy the device. A disadvantage of RTL is that the operating frequency is limited to 4 or 5 Mhz.

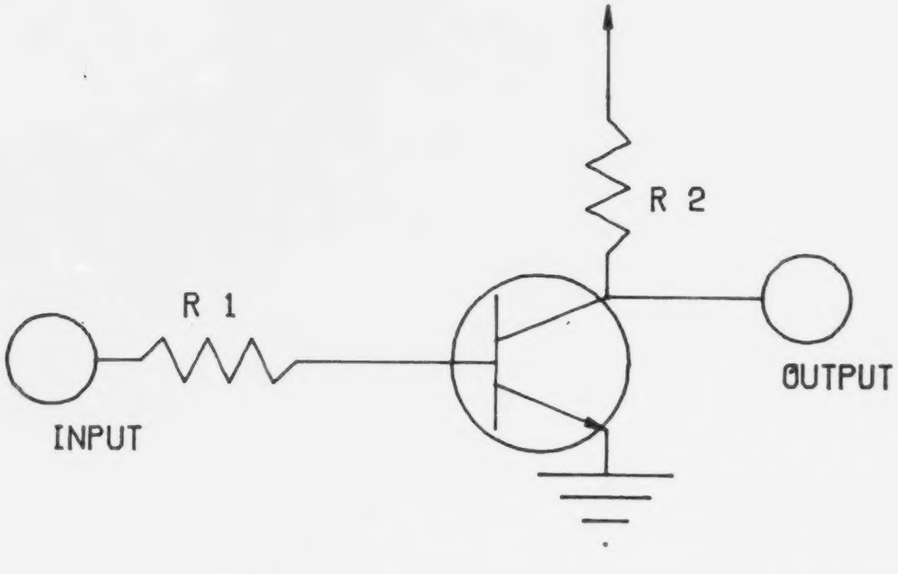


Figure E 1.3-1

Diode-transistor logic (DTL) is also among the earliest types available in IC form. Figure E 1.3-2 is an example of a DTL inverter. DTL operate from voltages of 5 to 6, and are now just about obsolete.

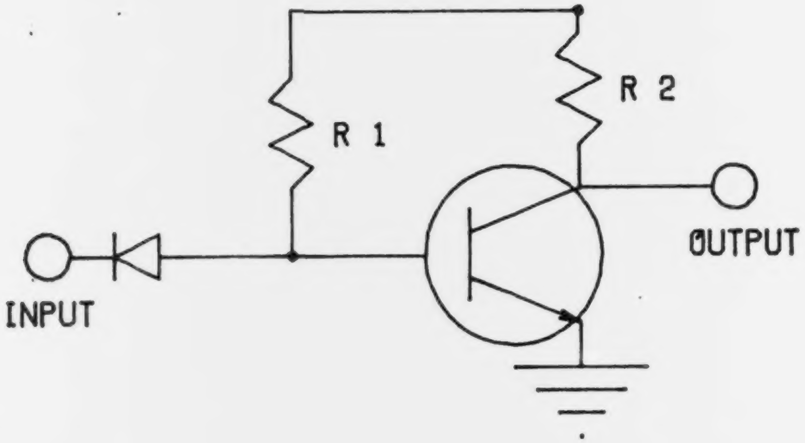


Figure E 1.3-2

Transistor-transistor logic (TTL) is perhaps the most common of all digital IC logic families. These ICs carry type numbers of 74xx and 74xxx.

A principal advantage of TTL is speed of operation. Almost all TTL devices operate at speeds of 18 to 20 Mhz. A disadvantage of TTL devices is the high power consumption. Logic levels of TTL devices are 0 to .8 volts for logic 0 and 2.4 to 5.0 volts for a logic 1. Any voltage between .8 and 2.4 is not defined and therefore considered invalid.

TTL devices normally require a plus 5 VOH supply and draw from 10 to 40 mA of current. A typical TTL inverter circuit is shown in Figure E 1.3-3. The circuit uses bipolar NPN transistors. A TTL output operates as a current sink. In high output, Qz is cut off and Q4 is turned on, connecting the output terminal to +V. When the output is low, Q4 is turned off, and Q3 is turned on. This puts the output to ground thru Q3. This is a typical digital circuit with two states, on or off.

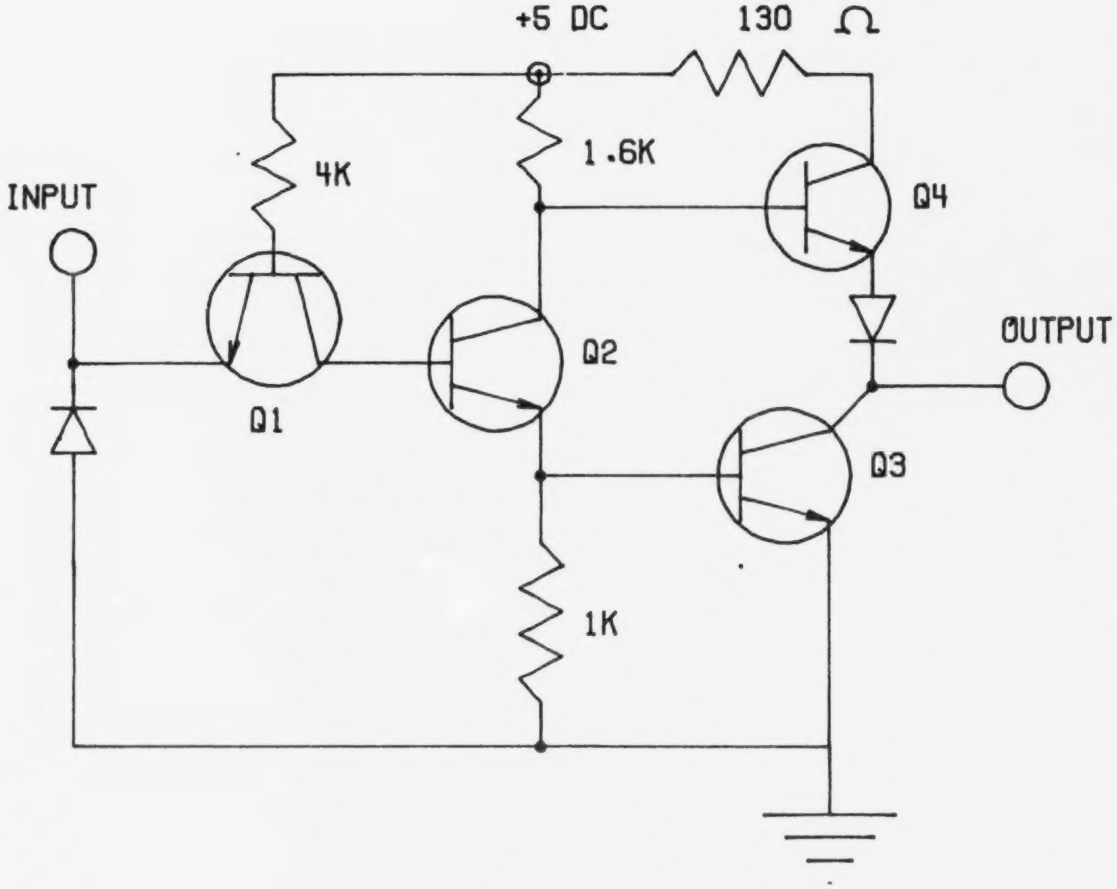


Figure E 1.3-3

The input of a TTL device is a current source formed by emitter follower Q1. The standard TTL input will source 1.6 mA of current. This can be defined as a "fan in" of 1. Every output can be specified as to "fan out." The typical 74xx/74xxx device has a fan out of 10. This means the output can sink 10X16 mA or 16 mA of current.

There are several sub-families of TTL devices: high power, low power, Schottky, and low-power Schottky. These differ a little from standard TTL, but can generally interface with standard TTL.

High-speed TTL devices are designated 74 Hxxx and have fan-out ratings of 10 to 12. They will source approximately

2.08 mA of current. The power consumption of 74H series is about twice that of the standard TTL. Its operating speed is in the range of 40 - 60 mhz.

Low-power TTL devices are designated 74Lxx/74Lxxx. Their power consumption is about one tenth that of standard TTL. Their main disadvantage is lack of speed. Typically they operate at frequencies up to 3 Mhz.

Schottky TTL devices are numbered as 74Sxx/74Sxxx and employ Schottky diodes across their inputs. The use of these diodes increases the operating speed. 74Sxx/74Sxxx devices can operate at speeds approaching 125 Mhz.

Low-power Schottky TTL devices carry the part number 74LSxx/74LSxxx. They operate at near the speed of Schottky devices, but consume about one fourth the power.

Complementary metal oxide semiconductors (CMOS) use insulated, gate-field-effect transistors. The term "complementary" in CMOS implies one or more transistor pairs consisting of a P-channel device and an N-channel device.

Up to this point all of the devices have had two states, high and low. Open-collector logic devices can give a third state, open or no connection, but only by giving up the logic high state. What is needed is a way of keeping both the logic states, high and low, and at the same time providing a third state, an open or disconnect state. The answer to this problem is what is called tri-state logic. The diagram drawn below is an example of a tri-state TTL inverter. The "dashed" circuitry is the addition of the tri-stating elements. Junctions added to the input and the pull-up transistor's base make it possible to disable these parts of the circuit. Remember, if the output transistors can be electronically disconnected, then the output will "float" at a high impedance condition and appear to be disconnected from the rest of the circuit.

The operation of the circuit is as follows: When the disable input is high transistor Q1 will be grounded and no current will be passed from the input to Q2; it has in effect been disconnected. A high on the disable input will also ground D1, which is a low impedance path for current away from the base of Q3. With Q2 off no current will flow to the base of Q4 and it will not be allowed to conduct. A high on the disable input has the effect of disconnecting the outputs, thus the tri-state. When the disable input is low, the junctions do not conduct and the device acts as a normal TTL inverter.

INFORMATION SHEET E 1.3 CONT'D

A Tri-State logic device is identified by a third input, the disable/enable input. The logic diagram for the tri-state device is also shown below.

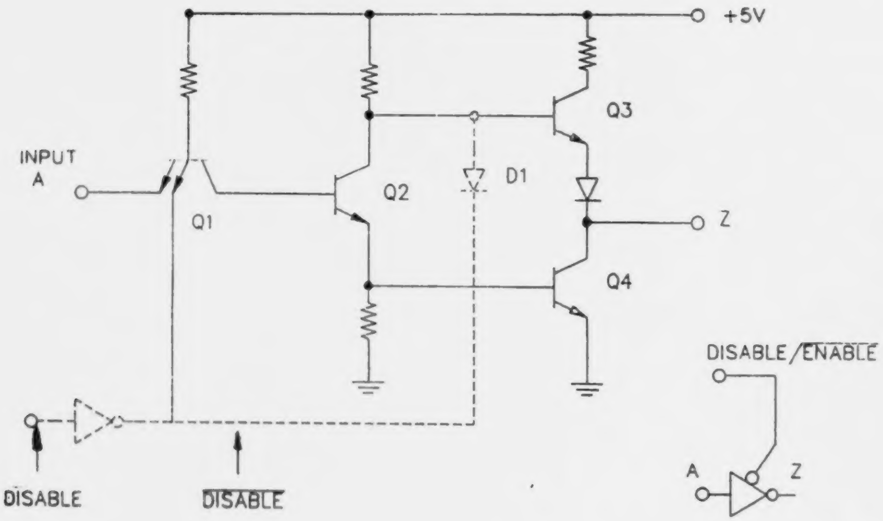

+5V
INPUT A
Q1
Q2
D1
Q3
Z
Q4
DISABLE
$\overline{\text{DISABLE}}$
DISABLE/$\overline{\text{ENABLE}}$
A
Z

Figure E 1.3-4

This figure is an example of a CMOS inverter. The CMOS inverter could be thought of as a pair of resistors in series across the DC power supply. They are configured so that one is at a high resistance when the other is at a low resistance. They are turned off or on by their respective gate voltage.

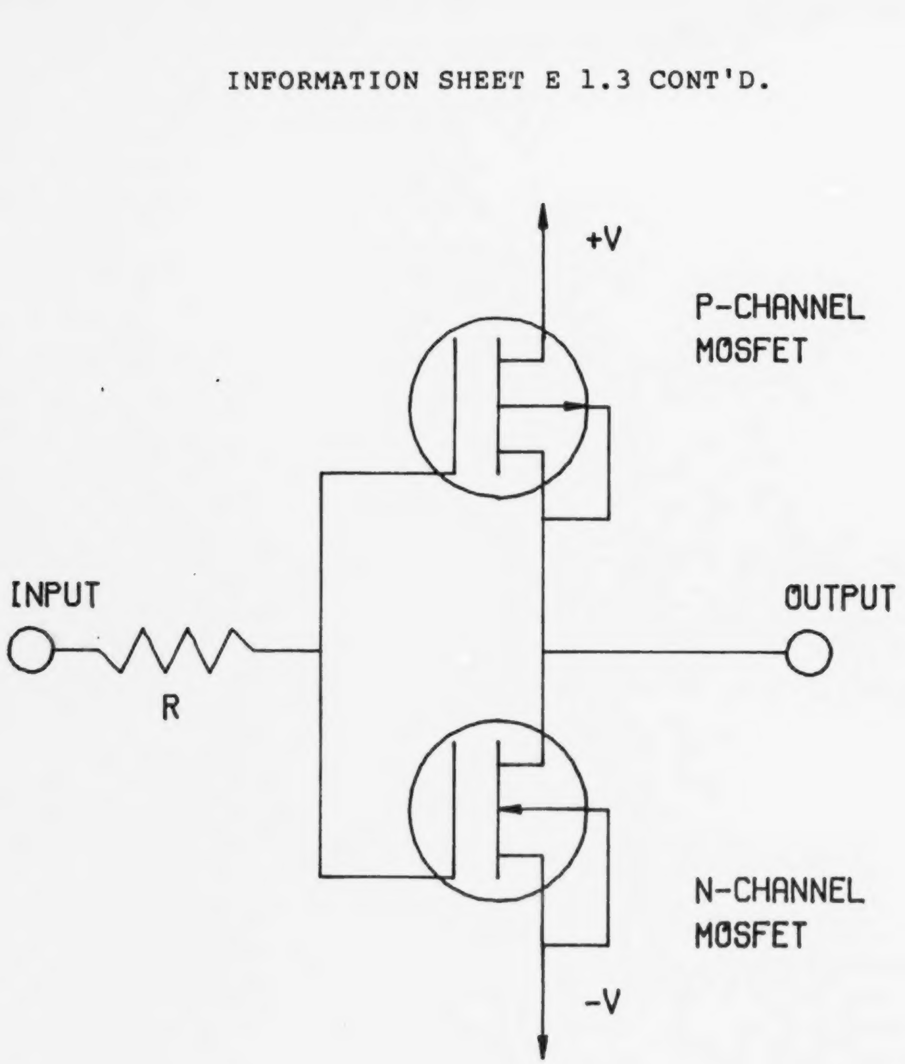


Figure E 1.3-5

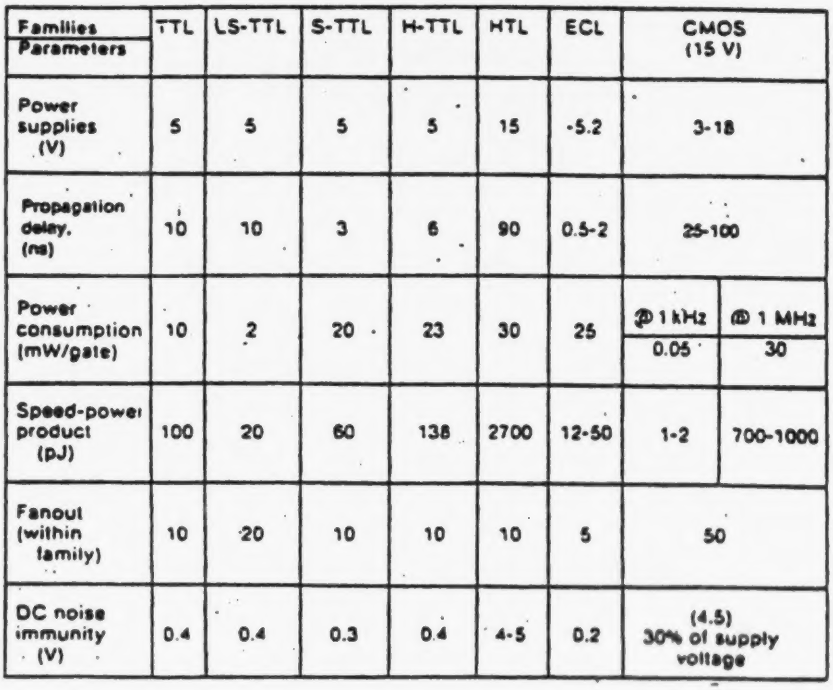
CMOS devices can operate from a wide range of voltages +- zero volts to +-18 volts. In some cases CMOS devices are operated at TTL voltages (+5 for +V and ground for -V); however, some designs set +V to ground and use a negative voltage for -V.

A disadvantage of CMOS is its slower speed, but it makes up for that with its extremely low power consumption. CMOS devices are used quite extensively in portable applications. CMOS is also fairly immune to noise. A disadvantage of the insulated gate employed in CMOS is its susceptibility to electro static damage. You must be very careful to discharge static voltage from your body and equipment before touching a CMOS device.

CMOS devices are numbered in the 40xx series or the 45xx series. They also have an "A" or "B" suffix indicating zener diode protection. The B-suffix CMOS contains internal zener diodes that shunt high voltage static charges away from gates. The B suffix also indicates a higher operating frequency.

Emitter-Coupled Logic (ECL) is not as popular or widely used as CMOS or TTL, but is far superior when it comes to speed. It also has a high immunity to noise. Its biggest disadvantage is its power consumption.

In summary, Figure E 1.3-6 gives a table of logic families and some of their characteristics. Not all of the logic families have been covered in this guide, and not all of the characteristics or circuit operations or configuration have been given. If you desire or need more information on logic families, check with your instructor for some additional reading.



Families / Parameters	TTL	LS-TTL	S-TTL	H-TTL	HTL	ECL	CMOS (15 V)	
Power supplies (V)	5	5	5	5	15	-5.2	3-18	
Propagation delay, (ns)	10	10	3	6	90	0.5-2	25-100	
Power consumption (mW/gate)	10	2	20	23	30	25	@ 1 kHz 0.05	@ 1 MHz 30
Speed-power product (pJ)	100	20	60	138	2700	12-50	1-2	700-1000
Fanout (within family)	10	20	10	10	10	5	50	
DC noise immunity (V)	0.4	0.4	0.3	0.4	4-5	0.2	(4.5) 30% of supply voltage	

Figure E 1.3-6

ACTIVITY SHEET

E 1.4

LOGIC FAMILIES

DIRECTIONS: Listed below are statements, diagrams or words that relate to various logic families. Match the logic family by placing its initials in the blank space for each item. Use (RTL, DTL, TTL, HTL, LS-TTL, S-TTL, ECL, and CMOS). Answers can be found on the next page.

1. ______________________ Almost obsolete
2. ______________________ 3-18 volts power supply
3. ______________________ Noise immunity very high
4. ______________________ Fastest of all families
5. ______________________ 3.6 to 4.0 volts
6. ______________________ 74xx/74xxx
7. ______________________ 4500 series
8. ______________________ Metal Oxide Semiconductor
9. ______________________ Fan out is 20
10. ______________________ A and B Suffix
11. ______________________ Static sensitive
12. ______________________ Fan-in about 1.3
13. ______________________ .5 to 2 nano second propagation delay

ACTIVITY SHEET E 1.4

ANSWER SHEET

1. DTL
2. CMOS
3. HTL
4. ECL
5. RTL
6. TTL
7. CMOS
8. CMOS
9. LS-TTL
10. CMOS
11. CMOS
12. HTL
13. ECL

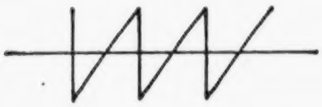
EXAM E 1.5

DIRECTIONS:

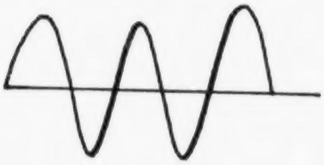
The purpose of this exam is to determine if you understand the information on Digital-and-Analog Circuits and Logic Families. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with the choice (A, B, C, D, or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, 80%.

1. Which signal below is an example of a digital signal?

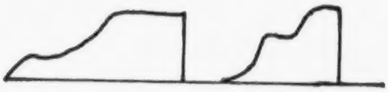
A.



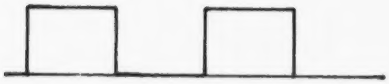
B.



C.



D.



E. None of these

2. The term which best describes an analog signal is ________.

A. Discrete
B. Continuous
C. Go-no-go
D. On-off
E. none of the above

3. Which of the following is not a digital device?

   A. Needle movement V.O.M.
   B. Sine wave
   C. Square wave
   D. A and C
   E. Calculator

4. Which of the following does not fit Emitter-Coupled Logic?

   A. Very fast
   B. High current
   C. Fan out = 5
   D. 15 volt supply
   E. All of these

5. The 74LSxx/74LSxxx part numbers are for which logic family?

   A. Transistor Transistor Logic
   B. Diode Transistor Logic
   C. Emitter-Coupled logic
   D. CMOS
   E. Low power Schottky

6. Which of the following power supply voltages apply to TTL logic?

   A. +5 volts
   B. 3-18 volts
   C. -5.2 volts
   D. 3.6 to 4.0 volts
   E. None of the above

7. Which of the following power supply voltages apply to CMOS logic?

   A. +5 volts
   B. 3 to 18 volts
   C. -5.2 volts
   D. All of these
   E. None of these

8. Which of the following families is very susceptible to static voltage?

   A. LS-TTL
   B. ECL
   C. RTL
   D. DTL
   E. None of these

9. Using a TTL device with a fan-out of 10, the output can sink ___________ of current?

   A. 15mA
   B. 20 mA
   C. 2.08mA
   D. 16mA
   E. 1.6mA

10. Which of the logic families listed below has the greatest noise immunity?

   A. RTL
   B. TTL
   C. DTL
   D. HTL

EXAM KEY E 1.5

1. D
2. B
3. D
4. D
5. E (could say TTL, but more specifically it is low Schottky power)
6. A
7. D (CMOS will work on all of these)
8. E (CMOS)
9. D
10. D

ELECTRONICS

ANALYZING DIGITAL ELECTRONIC CIRCUITS

E 2: NUMBERING SYSTEMS

TASK:	Use binary, decimal, octal and hexadecimal numbering systems.
PURPOSE:	Digital circuits operate on a binary system, (on-off). Because people use the decimal numbering system when working with digital circuits, it is necessary to understand and be able to convert between these two numbering systems. Microprocessors are digital devices which use the binary system; however, their programs are usually "loaded" via a hexadecimal key pad. After completing this learning guide you will understand both of these new numbering systems.
OBJECTIVE:	Given a written examination, you will use binary, decimal, octal and hexadecimal numbering systems. To master this task you must score 80% on a written exam.

ESTIMATED CLASS TIME: 3 HOURS

NUMBERING SYSTEMS

LEARNING STEPS

E 2

READ: Information Sheet E 2.1, "Binary Numbering System."

READ: Information on binary numbers on the following resource list.

COMPLETE: Activity Sheet E 2.2, "Binary to Decimal and Decimal to Binary."

READ: Information Sheet E 2.3, "Hexadecimal and Octal Numbering System."

READ: Information on hexadecimal and octal numbers on the following resource list.

COMPLETE: Activity Sheet E 2.4 "Hexadecimal and Octal to Decimal and Decimal to Octal and Hexadecimal."

REVIEW: All materials covered by this guide.

COMPLETE: Written Exam E 2.5. Contact your Instructor.

NUMBERING SYSTEMS

RESOURCES

E 2

1. CMOS DATA MANUAL (Motorola).
2. Brey, DIGITAL ELECTRONICS (Bobbs-Merrill, 1984).
3. Tokheim, DIGITAL ELECTRONICS TEXT AND ACTIVITY MANUAL (McGraw-Hill, 1984).
4. Tocci, DIGITAL SYSTEMS (Prentice-Hall, 1984).
5. DIGITAL TECHNIQUES STUDENT WORKBOOK (Heath Co., 1981).
6. Williams, DIGITAL TECHNOLOGY (SRA, 1982). 2nd Ed.
7. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Ed.
8. Texas Instrument TTL DATA MANUAL.

INFORMATION SHEET

E 2.1

BINARY NUMBERING SYSTEMS

There are several numbering systems used in digital electronics: decimal (base 10), binary (base 2), octal (base 8), and hexadecimal (base 16). The base of the numbering system refers to the number of distinct digits or symbols used. In base 2 there are only two symbols, 0 and 1. Base 16 (hex) has 16 symbols.

Before taking up the binary number system, you should review the decimal system. Table E 2.1-1 is an explanation of digit position and decimal value. The decimal system uses the digits 0 through 9 and has, therefore, a base (or radix) of 10. The value of each digit is determined by multiplying the digit by 10^{n-1}, where $\underline{n}$ is the number of the column in which the digit appears. In the decimal number 123, for example, the digits take their value as follows:

$$\underline{3} \times 10^{1-1} = 3 \times 10^{0} = 3 \times 1 = 3$$

$$\underline{2} \times 10^{2-1} = 2 \times 10^{1} = 2 \times 10 = 20$$

$$\underline{1} \times 10^{3-1} = 1 \times 10^{2} = 1 \times 100 = 100.$$

The total value is, thus, one hundred plus two tens plus three ones, or 123.

TABLE E 2.1-1

3	2	Radix column 1	0	Position
Thousands	Hundreds	Tens	Units	Name of Position
1,000	100	10	1	Position value in decimal form
10x10x10	10x10	10	$\frac{10}{10}$	Use of radix to form value of each position
10^3	10^2	10^1	10^0	Position value in exponential form

The most common and the most important of the numbering systems used in digital systems is the binary system. Binary means two. This system only uses two symbols, 0 and 1. This system lends itself exactly to the nature of a digital signal. That is, it has two distinct states, ON-OFF. The ON state usually is represented by the 1 digit, and the OFF state by the 0 digit. The only disadvantage to the binary system is that it takes so many digits to write a large number. For example, 15 base 10 is written 1111_2 in the binary system.

To begin your study of the binary system, look at Table E 2.1-2.

TABLE E 2.1-2

	4	3	2	1	0	Position	-1	-2	-3	-4	
	Sixteens	Eights	Fours	Twos	Units	Name of Position	0.1	0.01	0.001	0.0001	
	16	8	4	2	1	Position value in decimal form	2/4 or 1/2	2/8 or 1/4	2/16 or 1/8	2/32 or 1/16	
2x2x2...	2x2x2x2	2x2x2	2x2	2	2/2	Use of radix to form value of each position	$2^1/2^2$	$2^1/2^3$	$2^1/2^4$	$2^1/2^5$	
2^n	2^4	2^3	2^2	2^1	2^0	Position value exponential form	2^{-1}	2^{-2}	2^{-3}	2^{-4}	2^{-n}

Note the following things: (1) The center column "Position" gives the position value in decimal form, use of radix for value position, and exponential position. (2) Each column to the left doubles; to the right each column halves. (3) Finally, recognize that the table could go in either direction to infinity.

Let's use this table to convert a binary number to the more familiar decimal system. Many times it is easier to think in terms of the decimal system rather that the binary system. Convert 1001_2 to a decimal number. There are 4 digits and each has its own weight. Let's put the weight above each digit.

Weight:	8 4 2 1
Digit:	1 0 0 1

What this "says" is you have one 8, no 4's, no 2's, and one 1. If these are now added together the decimal equivalent is 8 + 1 = 9_{10}.

At this point it might be wise to mention that the largest value is called MSD or "Most Significant Digit." LSD stands for "Least Significant Digit" and names to the smallest value holder. This terminology can be used with any numbering system. Sometimes the "D" in MSD and LSD is replaced with a "B." The "B" stands for bit.

Many times a decimal number has to be converted to a binary number. This conversion can be handled in several ways. The first method is to reverse the process we used earlier.

Another method is very similar to the table method; however, it involves division by two. Look at Figure E 2.1-1 to see how to convert 25_{10} to binary by this method.

25/2 = 12 + remainder of 1 = LSD

12/2 = 6 + remainder of 0

6/2 = 3 + remainder of 0

3/2 = 1 + remainder of 1

1/2 = 0 + remainder of 1 = MSD

$11001_2 = 25_{10}$

FIGURE E 2.1-1

ACTIVITY SHEET

E 2.2

BINARY TO DECIMAL AND DECIMAL TO BINARY

DIRECTIONS: For this activity you will be converting between the binary and decimal numbering systems. On a separate sheet of paper convert the following numbers: (You may use the conversion charts in the guide.)

1. 1010_2 ______________________ $_{10}$
2. 111011_2 ______________________ $_{10}$
3. 11.01_2 ______________________ $_{10}$
4. 11111101_2 ______________________ $_{10}$
5. $.010101_2$ ______________________ $_{10}$
6. 14_{10} ______________________ $_2$
7. 250_{10} ______________________ $_2$
8. $.250_{10}$ ______________________ $_2$
9. 1024_{10} ______________________ $_2$
10. $.375_{10}$ ______________________ $_2$

If you have trouble converting these, you should review the information sheet, and ask your instructor for some additional reading of the binary numbering system. If this process is clear to you, proceed to the next learning step.

ACTIVITY SHEET E 2.2

ANSWER SHEET

1. 10_{10}
2. 59_{10}
3. 3.25_{10}
4. 253_{10}
5. 0.328125_{10}
6. 1110_2
7. 11111010_2
8. 0.01_2
9. 10000000000_2
10. $.011_2$

INFORMATION SHEET

E 2.3

HEXADECIMAL AND OCTAL NUMBERING SYSTEMS

The hexadecimal numbering system is a base 16 system. There are 16 symbols used in the hex system. A number written in hex would look like this: 10_H. The subscript H indicates the number is a hexadecimal number, not a decimal 10. Table E 2.3-1 shows the hex symbols and their binary and decimal equivalence. Note the characters used for ten and above in the hex column. These are symbols unique to the hexadecimal system. The hex system is easily used to represent large numbers due to its larger base. Table E 2.3-2 relates to hex numbers position, exponential form and its decimal equivalency. Note that with just a few hex symbols you can write a large decimal number.

Table E 2.3-1

HEX	DECIMAL	BINARY
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
A	10	1010
B	11	1011
C	12	1100
D	13	1101
E	14	1110
F	15	1111

INFORMATION SHEET E 2.3 CONT'D.

Table E 2.3-2

3	2	1	0	Position	-1	-2	-3
16^3	16^2	16^1	16^0	Exponential Form	16^{-1}	16^{-2}	16_{-3}
4096	256	16	1	Decimal Value	.6250	.390625	.24414

Many times it is more convenient to think in terms of the decimal system rather than hexadecimal. What must be done is a hexadecimal to decimal conversion. There are many charts available for this conversion; however, when no chart is near this technique will meet your needs.

Procedure:

A. Multiply the most significant digit (MSD) for the hexadecimal number by the given base (16), and add the next digit.

B. Multiply this result by the given base (16), and add the next digit.

C. Repeat until every digit in the number has been used.

Example: $A1F_H$ to decimal. (Hint: remember you must convert the hex symbol to its decimal equal.)

1. A * 16 + next number (1)=
   10 * 16 + 1 = 161

2. 161 * 16 + F =
   161 * 16 + 15 = 2591_{10}

3. Finished ? Yes. $A1F_H = 2591_{10}$

(This technique will also work for converting binary to decimal.)

Sometimes it is required to convert a decimal number into a hexadecimal number. Again, there are many charts that can be used for this process: however, a conversion technique will aid when a chart is not available.

Procedure:
A. Divide the given base 10 number by 16.
B. If there is no remainder, record a 0 in the remainder row. If there is a remainder, record that remainder in the remainder row.
C. Divide the quotient from the preceding step by 16 and record any remainder.
D. Repeat process until quotient is 0.

Example: Convert 536_{10} into hexadecimal.

Step 3

$$\begin{array}{r} 0 \\ 16\overline{)2} \end{array}$$

Step 2

$$\begin{array}{r} 2 \\ 16\overline{)33} \\ \underline{32} \\ 1 \end{array}$$

Start

$$\begin{array}{r} 33 \\ 16\overline{)536} \\ \underline{48} \\ 56 \\ \underline{48} \\ 8 \end{array}$$

MSD 2 1 8 LSD

Check: 2-256 1-16 8 ones

512 + 16 + 8 = 536_{10} = 218_{16}

OCTAL NUMBERING SYSTEM

The octal number system is a Base 8 system, consisting of the digits 0 through 7. It is a positional value system with digits identified from the least significant to the most.

Counting to the octal system is fairly straight forward and is similar to that of decimal counting. When counting in the octal system, start with zero in the first position and take each digit in progression until 7 is reached. Then add a one to the next higher position and start over with a zero in the first position. This process continues until the count of 77 is reached. Then add a one in the third position and start with zeros in the first two positions. The same pattern is followed continuously until any desired number is reached.

Table E 2.3-3 illustrates the powers of 8. The "n" in the center column is the power of 8 and the outside columns are 8 raised to the n power.

TABLE E 2.3-3

8^n	n	8^{-n}
1	0	1.0
8	1	.125
64	2	.015 625
512	3	.001 953
4 096	4	.000 244
32 768	5	.000 030
262 144	6	
2 097 152	7	
16 777 216	8	
134 217 728	9	
1 073 741 820	10	

INFORMATION SHEET E 2.3 CONT'D.

In order to convert a number in any system to the equivalent number written in decimal, simply write the number in the polynomial form as shown in Table E 2.3-3. For example, convert 153 base 10 to octal.

The largest power of 8 in 153 is 64, 8 to the second. Now divide 64 into 153. 64 will divide into 153 two times, plus. Second, multiply 2 x 64 = 128 and subtract that number from 153. This is equal to 25. The next power of 8 that will go into 25 is 8, 8 to the first. Divide 8 into 25. Eight will divide into 25 3 times plus. Next multiply 3 x 8 = 24. Subtract this from the previous remainder, 25 this leaves 1, which is the value 8 to the zero power. Follow the detail listed below:

153 is your decimal number.

153 divide 64 = 128 Value of 2 in this place

153 128 = 25 Amount remaining in number.

25 divide 8 = 3 Number of times this power of 8 is in the number.

3 x 8 = 24 Value of 3 in this place.

25 24 = 1 Amount remaining in number

No power of 8 goes into 1; therefore, write the octal number.

$$(2 \times 8_2) + (3 \times 8_1) + (1 \times 8_0) = 231$$

153 base 10 = 231 base 8

To convert a decimal number to octal use the "divide by the base method." The procedure is as follows:

Convert 168 base 10 to octal.

1. 168 /8 = 21 remainder = 0. Record as least significant digit.
2. 2 / 8 = 2 remainder = 5. Record as next least sig. digit.
3. 2 / 8 = 0 remainder = 2. This is your most significant digit.
4. Final answer is: 250 base 8.

To convert an octal number to decimal use Table number 3 on the preceding page.

INFORMATION SHEET E 2.3 CONT'D.

Conversion from binary to octal is simply a matter of taking the binary bits in groups of three and replacing them with the octal equivalent, while keeping the places in order.

010 110 011 001 binary number

2 6 3 1 octal number

The conversion charts and techniques listed are only a small sample of the many available. If you would like more information on this topic contact your instructor. If you feel you understand the information proceed to the next listed learning step.

INFORMATION SHEET E 2.3 CONT'D.

HEXADECIMAL NUMBERING SYSTEM

POWERS OF 16 (IN BASE 10)

16^n	n	16^{-n}
1	0	0.10000 00000 00000 00000 × 10
16	1	0.62500 00000 00000 00000 × 10^{-1}
256	2	0.39062 50000 00000 00000 × 10^{-2}
4 096	3	0.24414 06250 00000 00000 × 10^{-3}
65 536	4	0.15258 78906 25000 00000 × 10^{-4}
1 048 576	5	0.95367 43164 06250 00000 × 10^{-6}
16 777 216	6	0.59604 64477 53906 25000 × 10^{-7}
268 435 456	7	0.37252 90298 46191 40625 × 10^{-8}
4 294 967 296	8	0.23283 06436 53869 62891 × 10^{-9}
68 719 476 736	9	0.14551 91522 83668 51807 × 10^{-10}
1 099 511 627 776	10	0.90949 47017 72928 23792 × 10^{-12}
17 592 186 044 416	11	0.56843 41886 08080 14870 × 10^{-13}
281 474 976 710 656	12	0.35527 13678 80050 09294 × 10^{-14}
4 503 599 627 370 496	13	0.22204 46049 25031 30808 × 10^{-15}
72 057 594 037 927 936	14	0.13877 78780 78144 56756 × 10^{-16}
1 152 921 504 606 846 976	15	0.86736 17379 88403 54721 × 10^{-18}

POWERS OF 10 (IN BASE 16)

10^n	n	10^{-n}
1	0	1.0000 0000 0000 0000
A	1	0.1999 9999 9999 999A
64	2	0.28F5 C28F 5C28 F5C3 × 16^{-1}
3E8	3	0.4189 374B C6A7 EF9E × 16^{-2}
2710	4	0.68DB 8BAC 710C B296 × 16^{-3}
1 86A0	5	0.A7C5 AC47 1B47 8423 × 16^{-4}
F 4240	6	0.10C6 F7A0 B5ED 8D37 × 16^{-4}
98 9680	7	0.1AD7 F29A BCAF 4858 × 16^{-5}
5F5 E100	8	0.2AF3 1DC4 6118 73BF × 16^{-6}
3B9A CA00	9	0.44B8 2FA0 9B5A 52CC × 16^{-7}
2 540B E400	10	0.6DF3 7F67 5EF6 EADF × 16^{-8}
17 4876 E800	11	0.AFEB FF0B CB24 AAFF × 16^{-9}
E8 D4A5 1000	12	0.1197 9981 2DEA 1119 × 16^{-9}
918 4E72 A000	13	0.1C25 C268 4976 81C2 × 16^{-10}
5AF3 107A 4000	14	0.2D09 370D 4257 3604 × 16^{-11}
3 8D7E A4C6 8000	15	0.480E BE7B 9D58 566D × 16^{-12}
23 8652 6FC1 0000	16	0.734A CA5F 6226 F0AE × 16^{-13}
163 4578 5D8A 0000	17	0.B877 AA32 36A4 B449 × 16^{-14}
DE0 B6B3 A764 0000	18	0.1272 5DD1 D243 ABA1 × 16^{-14}
8AC7 2304 89E8 0000	19	0.1D83 C94F B6D2 AC35 × 16^{-15}

ACTIVITY SHEET

E 2.4

HEXADECIMAL AND DECIMAL

DIRECTIONS: For this activity you will be converting between the hexadecimal and decimal numbering systems. On a separate sheet of paper convert the following numbers.

1. $34A_H$ to ____________________$_{10}$
2. $F2AC_H$ to ____________________$_{10}$
3. $F21_H$ to ____________________ $_{10}$
4. $ABC8_H$ to ____________________$_{10}$
5. $98A_H$ to ____________________$_{10}$
6. 382_{10} ____________________$_H$
7. 2810_{10} ____________________$_H$
8. $4{,}982_{10}$ ____________________ $_H$
9. $20{,}812_{10}$ ____________________ $_H$
10. $1{,}482_{10}$ ____________________ $_H$

If you have trouble converting these, you should review the information sheet, and ask your instructor for some additional reading or activities on the hexadecimal numbering system. If this process is clear to you, proceed to the next learning step.

ACTIVITY SHEET

E 2.4

OCTAL AND DECIMAL

Convert the following octal numbers to binary.

1. 361
2. 277
3. 532
4. 464
5. 106
6. 737
7. 5266
8. 4137
9. 7777
10. 1000

Convert the following binary numbers to octal.

1. 000101
2. 11001
3. 11101
4. 0011
5. 110111101
6. 100100011
7. 11001100
8. 110111101
9. 001001111
10. 101011000

ACTIVITY SHEET E 2.4

ANSWER SHEET

Hexadecimal:

1. 842_{10}
2. $62, 124_{10}$
3. 3873_{10}
4. $43,976_{10}$
5. 2442_{10}
6. $17E_H$
7. AFA_H
8. 1376_H
9. $514C_H$
10. $5CA_H$

Octal: Binary

1. 11 010 001
2. 10 111 111
3. 101 011 010
4. 100 110 100
5. 1 000 110
6. 111 011 111
7. 101 010 110 110
8. 100 001 011 111
9. 111 111 111 111
10. 1 000 000 000

ACTIVITY SHEET E 2.4 CONT'D.

Binary: Octal

1. 5

2. 31

3. 35

4. 3

5. 675

6. 443

7. 314

8. 675

9. 117

10. 530

EXAM E 2.5

DIRECTIONS:

The purpose of this exam is to determine whether or not you understood the information on binary, decimal, octal and hexadecimal, numbering systems. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, 80%.

EXAM E 2.5 CONT'D.

Convert the following decimal numbers to binary numbers:

1. 120_{10}
    - a) 1110101_{2}
    - b) 1100111_{2}
    - c) 1011000_{2}
    - d) 1111000_{2}
2. 4082_{10}
    - a) 111111110010_{2}
    - b) 111110001_{2}
    - c) 1010101010_{2}
    - d) 1111100111_{2}
3. 358_{10}
    - a) 110100110_{2}
    - b) 101100110_{2}
    - c) 11100110_{2}
    - d) 11111111_{2}

Convert the following binary numbers to decimal numbers:

4. 1011_{2}
    - a) 12_{10}
    - b) 11_{10}
    - c) 15_{10}
    - d) 13_{10}
5. 101010_{2}
    - a) 42_{10}
    - b) 40_{10}
    - c) 38_{10}
6. 111101_{2}
    - a) 58_{10}
    - b) 52_{10}
    - c) 61_{10}
    - d) 48_{10}

Convert the following hexadecimal numbers to decimal numbers:

7. $0A8_H$
   a) 168_{10}
   b) 172_{10}
   c) 198_{10}
   d) 158_{10}

8. $0F1A_H$
   a) $4,088_{10}$
   b) $3,866_{10}$
   c) $3,286_{10}$
   d) $3,981_{10}$

Convert the following decimal numbers to hexadecimal:

9. $10,101_{10}$
   a) 2749_H
   b) $2ACB_H$
   c) 2775_H
   d) $3AEC_H$

10. $4,928_{10}$
    a) $134B_H$
    b) $134A_H$
    c) $12AC_H$
    d) 1340_H

11. 721 octal to decimal.
    a) 605
    b) 506
    c) 209
    d) none of these

EXAM E 2.5 CONT'D.

12. 634 octal to binary.

a) 11011010

b) 011 110 100

c) 110 011 100

d) none of these

EXAM KEY E 2.5

1. D
2. A
3. B
4. B
5. A
6. C
7. A
8. B
9. C
10. D
11. A
12. C

ANALYZING DIGITAL ELECTRONIC CIRCUITS

E 3: BOOLEAN LOGIC

TASK: Verify basic Boolean expressions using truth tables and logic gates.

PURPOSE: Logic gates are the basic building blocks for all digital circuits. These gates have binary inputs for operation; therefore, they are referred to as binary gates. They are called "logic" gates because they will yield a particular output with a given set of inputs, hence their operation is "logical." After completing this learning guide you should have memorized the logic symbol for each gate and its characteristics. This information is essential for any person working in the field of computers or digital electronics.

OBJECTIVE: Given access to necessary tools and equipment, you will verify basic Boolean expressions using truth tables and integrated circuit logic gates. To master this task you must score 80% on a written examination and a performance checklist.

ESTIMATED CLASS TIME: 12 HOURS

BOOLEAN LOGIC

LEARNING STEPS

E 3

READ:	Information Sheet E 3.1, "Logic Gate Data and Breadboarding."
READ:	Information on TTL or CMOS Ic Data from the following resource list.
COMPLETE:	Activity Sheet E 3.2, "IC Logic Gate Data."
READ:	Information Sheet E 3.3, "Gate Symbols and Truth Tables."
READ:	Information on combinational logic from the following resource list.
COMPLETE:	Activity Sheet E 3.4, "Gate Symbols and Truth Tables."
READ:	Information Sheet E 3.5, "Multiple-Input Gates."
COMPLETE:	Activity Sheet E 3.6, "Multiple-Input Gates."
REVIEW:	All material covered by this learning guide.
COMPLETE:	Performance Checklist E 3.7. Contact your instructor.
COMPLETE:	Written Exam E 3.8. Contact your instructor.

BOOLEAN LOGIC

RESOURCES

E 3

1. CMOS DATA MANUAL (Motorola).
2. Brey, DIGITAL ELECTRONICS (Bobbs-Merrill, 1984).
3. Tokheim, DIGITAL ELECTRONICS TEXT AND ACTIVITY MANUAL (McGraw-Hill, 1984).
4. Tocci, DIGITAL SYSTEMS (Prentice-Hall, 1984).
5. DIGITAL TECHNIQUES STUDENT WORKBOOK (Heath Co., 1981).
6. Williams, DIGITAL TECHNOLOGY (SRA, 1982). 2nd Ed.
7. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Ed.
8. Texas Instrument TTL DATA MANUAL.

INFORMATION SHEET

E 3.1

LOGIC GATE DATA AND BREADBOARDING

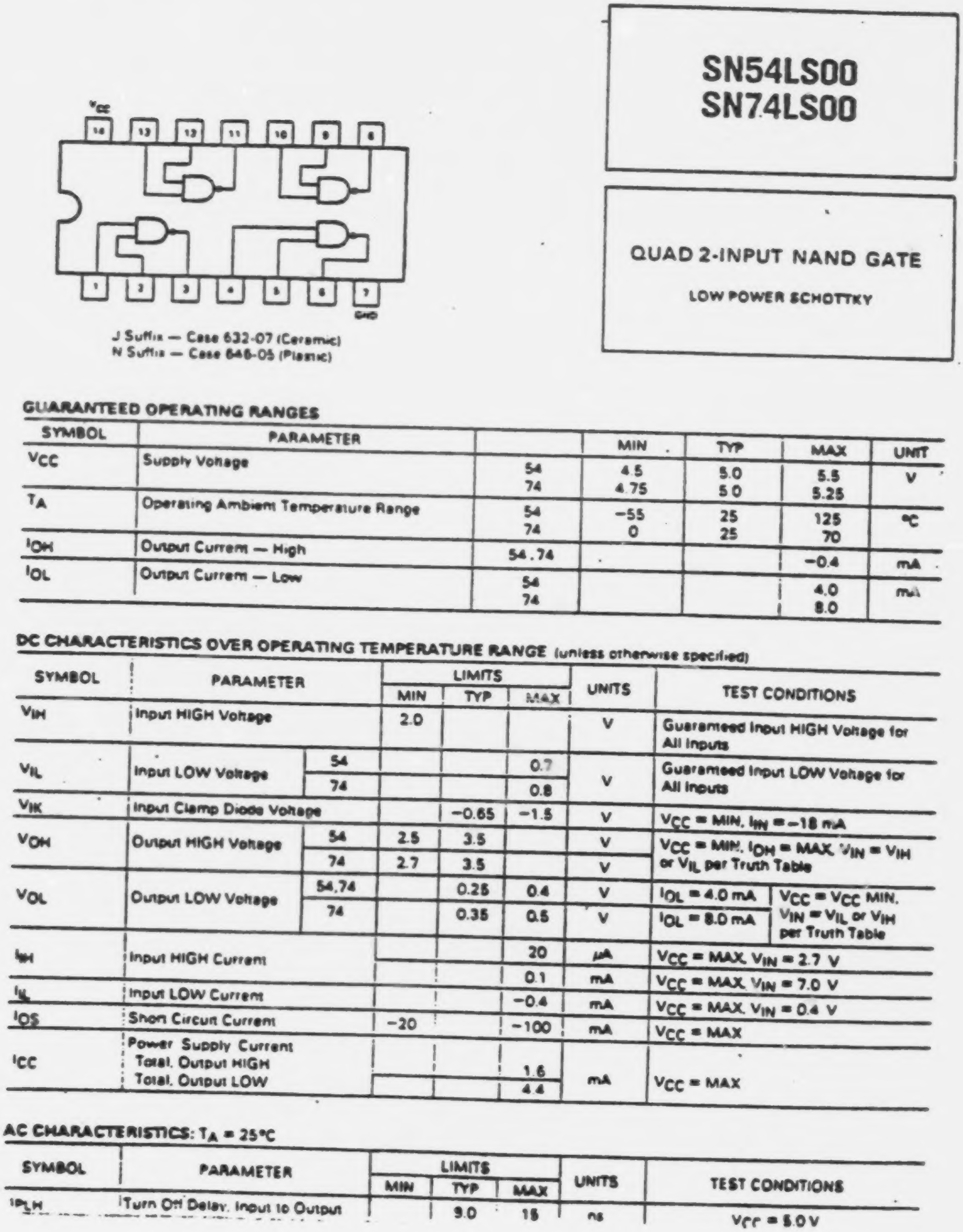
The logic gates used will probably be from one of two families, TTL or CMOS. These are the easiest to purchase and the most popular. Each integrated circuit will have a number printed on the top of the "chip" (IC). This number refers to the type of gates the chip contains. Examples of these numbers are as follows:

TTL 74XX
7400 - Four 2 input NAND Gates
7402 - Four 2 input NOR Gates
7408 - Four 2 input AND Gates
7404 - Six Inverter Gates
7432 - Four 2 input OR Gates
7486 - Four 2 input XOR Gates

CMOS 40XX
4001B - Quad (Four) 2-Input NOR Gate
4011B - Quad - 2 - Input NAND Gate
4070B - Quad 2-Input XOR Gate
4071B - Quad 2-Input OR Gate
4081B - Quad 2-Input AND Gate
4049B - Hex(6) Inverter

The integrated circuit is a sealed unit. It cannot be taken apart for repair or identification. To understand the function of each pin, you must use the manufacturer's data sheets. Figure E 3.1-1 is an example of a data sheet for a 74LS00. Notice the manufacturer has drawn a "picture" of how the gates are arranged inside the chip. This is called a "pin-out" and will be used to connect the IC to power, ground and other logic components.

INFORMATION SHEET E 3.1 CONT'D.


VCC
14
13
12
11
10
9
8
1
2
3
4
5
6
7
GND

J Suffix — Case 632-07 (Ceramic)
N Suffix — Case 646-05 (Plastic)

SN54LS00
SN74LS00

QUAD 2-INPUT NAND GATE

LOW POWER SCHOTTKY

GUARANTEED OPERATING RANGES

SYMBOL	PARAMETER		MIN	TYP	MAX	UNIT
V_{CC}	Supply Voltage	54 74	4.5 4.75	5.0 5.0	5.5 5.25	V
T_A	Operating Ambient Temperature Range	54 74	−55 0	25 25	125 70	°C
I_{OH}	Output Current — High	54, 74			−0.4	mA
I_{OL}	Output Current — Low	54 74			4.0 8.0	mA

DC CHARACTERISTICS OVER OPERATING TEMPERATURE RANGE (unless otherwise specified)

SYMBOL	PARAMETER		LIMITS			UNITS	TEST CONDITIONS	
			MIN	TYP	MAX			
V_{IH}	Input HIGH Voltage		2.0			V	Guaranteed Input HIGH Voltage for All Inputs	
V_{IL}	Input LOW Voltage	54			0.7	V	Guaranteed Input LOW Voltage for All Inputs	
		74			0.8			
V_{IK}	Input Clamp Diode Voltage			−0.65	−1.5	V	V_{CC} = MIN, I_{IN} = −18 mA	
V_{OH}	Output HIGH Voltage	54	2.5	3.5		V	V_{CC} = MIN, I_{OH} = MAX, V_{IN} = V_{IH} or V_{IL} per Truth Table	
		74	2.7	3.5		V		
V_{OL}	Output LOW Voltage	54, 74		0.25	0.4	V	I_{OL} = 4.0 mA	V_{CC} = V_{CC} MIN, V_{IN} = V_{IL} or V_{IH} per Truth Table
		74		0.35	0.5	V	I_{OL} = 8.0 mA	
I_{IH}	Input HIGH Current				20	µA	V_{CC} = MAX, V_{IN} = 2.7 V	
					0.1	mA	V_{CC} = MAX, V_{IN} = 7.0 V	
I_{IL}	Input LOW Current				−0.4	mA	V_{CC} = MAX, V_{IN} = 0.4 V	
I_{OS}	Short Circuit Current		−20		−100	mA	V_{CC} = MAX	
I_{CC}	Power Supply Current Total, Output HIGH Total, Output LOW				 1.6 4.4	mA	V_{CC} = MAX	

AC CHARACTERISTICS: T_A = 25°C

SYMBOL	PARAMETER	LIMITS			UNITS	TEST CONDITIONS
		MIN	TYP	MAX		
t_{PLH}	Turn Off Delay, Input to Output		9.0	15	ns	V_{CC} = 5.0 V

Figure E 3.1-1

The activities used in this and other learning guides will require you to "breadboard" and test certain logic circuits. This will usually be accomplished on a breadboarding logic system of some kind. The system you use will depend on what your instructor has available. It will be to your advantage to be as familiar with this system as possible before you breadboard and study binary logic gates.

Your system may or may not include logic trouble-shooting equipment. If it does, consider yourself fortunate. Some simple pieces of troubleshooting equipment might be a probe, a pulser, and a logic clip.

The logic probe is a simple device which allows you to "probe" the logic. It allows you to look at the input logic (voltage) and output logic on each pin of the IC. Figure E 3.1-2 is an example of a simple probe.

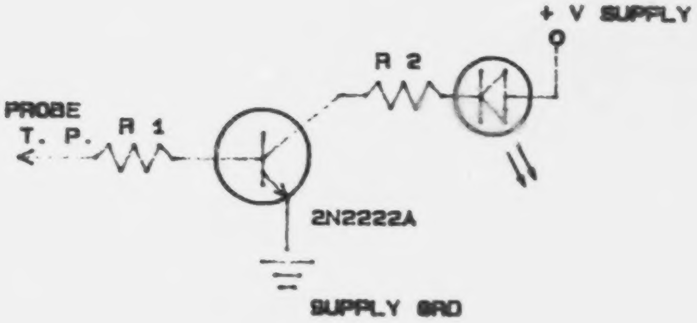


Figure E 3.1-2

The circuit would usually be housed in a pencil like tube with long wires and alligator clips going to the + supply and ground. If the probe is touched to logic 1 (high voltage) the LED would light. If touched to a logic 0 (ground) no light would be displayed. This device allows you to probe around the circuit "looking" at the logic.

A logic pulser is a device which provides a single pulse (a quick transition from logic 0 to 1) or a series of pulses. It is used to pulse or trigger the logic input. Pulsers can be very complicated devices costing hundreds of dollars or a device as simple as that shown in Figure E 3.1-3.

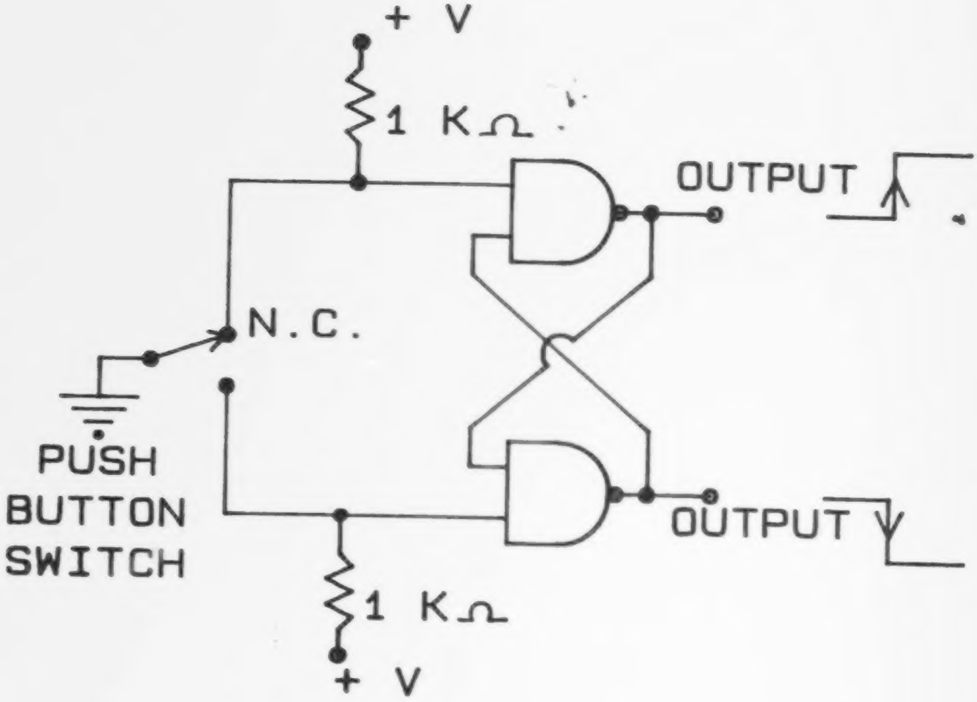


Figure E 3.1-3

The pulser is used along with the probe to troubleshoot logic devices.

A logic clip is a device that you clip over the IC. It allows you to monitor the logic on all of the pins at the same time. These devices are sold by the number of pins they can connect to, i.e., 14 pin, 16 pin, 24 pin, etc. Figure E 3.1-4 is an example of a logic clip.

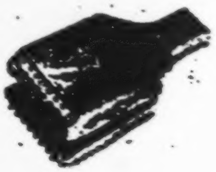


Figure E 3.1-4

All logic families have what are called valid logic levels. These are voltages which the IC recognizes as valid for logic 0 or logic 1. Figure E 3.1-5 is a graph illustrating this idea. When using TTL a valid logic low is from zero to 0.8 volts. A valid high is from 2.4 to 5.0 volts. Any voltage between 2.4 and 0.8 is considered invalid. When using CMOS the input voltage specification is interpreted as the worst-case input voltage to produce an output level of "1" or "0." The "zero" or valid "low" state "1" output level is defined as a deviation from the supply (VCC) and ground levels. For 5.0 V supply, this deviation is 0.5 volts; for 10.0 V supply, 1.0 V and for 15 V, 1.5 V. An an example a CMOS device operating from 5.0 V supply would be guaranteed to switch on before 3.5 V and not to switch on up 1.5 V. Switching and not switching are defined as within 0.5 V of the ideal output level for the example of a 5.0 V supply. The actual switch level referred to the input, is between 1.5 V and 3.5 V. This may seem a little confusing when compared to TTL, but remember you are working with voltage activated devices in CMOS and current controlled devices with TTL. The point of your valid low will be between 0 and 1.5 and valid high will be between 3.0 and 5.0 volts.

Most of the logic systems use positive logic: a logic "1" is a positive-going voltage and a logic "0" is a negative-going voltage. There is a negative logic system; its operation is opposite to the positive type. A logic "1" is a negative voltage while a logic "0" is a less negative or positive voltage. In negative logic, gate "turn-on" occurs because of a "negative-going" input (high negative voltage). An output from a negative logic gate would be in the negative direction from ground, or near ground, to a high negative value. As you can see, this is the opposite of positive logic. As a technician you need to recognize both logic systems.

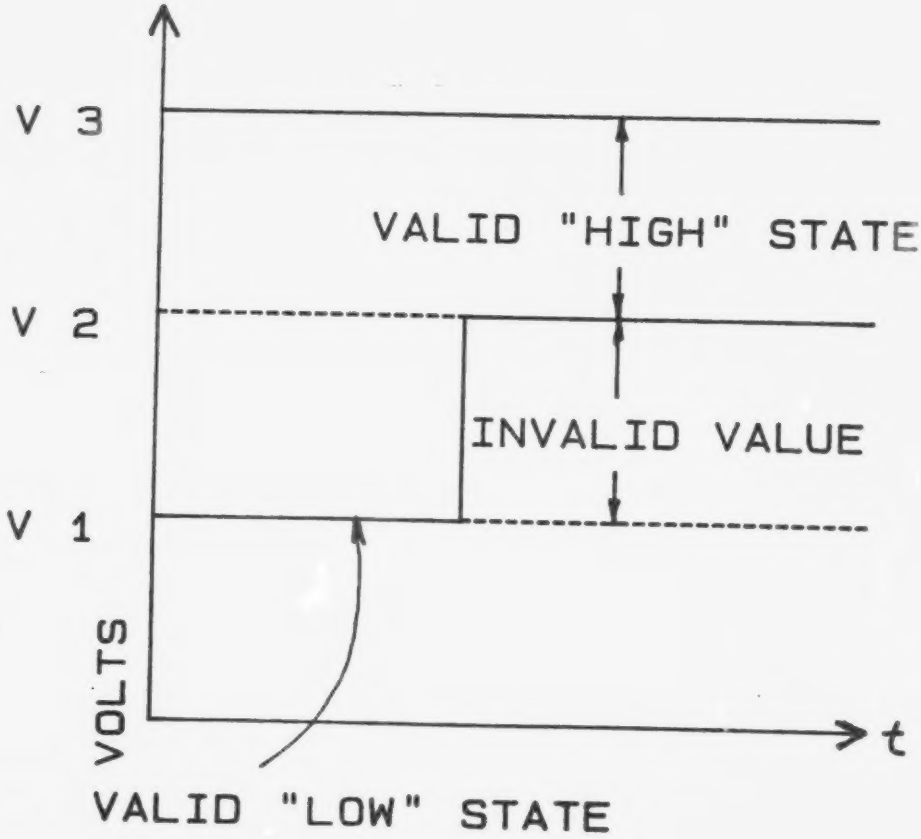

V 3
VALID "HIGH" STATE
V 2
INVALID VALUE
V 1
VOLTS
t
VALID "LOW" STATE

Figure E 3.1-5

ACTIVITY SHEET

E 3.2

IC LOGIC GATE DATA

DIRECTIONS: Answer all the questions and fill in all of the blanks listed on this activity sheet. (Use separate sheet of paper)

1. Why are TTL and CMOS logic families used for the study of digital electronics?

2. Match the following: (See Figure E 3.2-1)

   a. 7400
   b. 7402
   c. 4081
   d. 4049
   e. 7486

   XOR
   AND
   Hex Inverter
   NOR
   NAND

   Pin 14 ________________

   Pin 1 ________________

   Pin 7 ________________

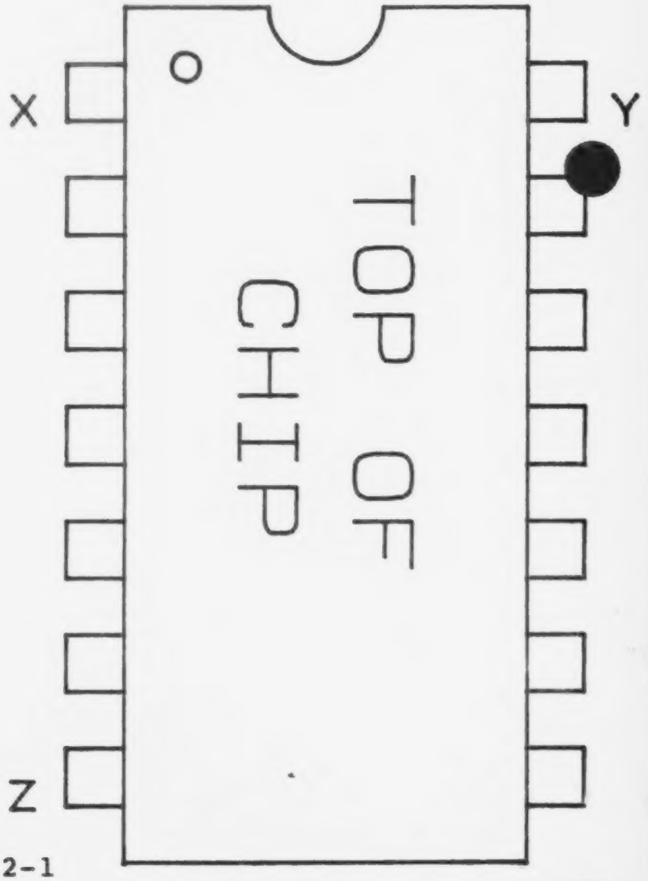


Figure E 3.2-1

3. Using a TTL data book identify these 74XX series chips.

7410 ______________________________

7430 ______________________________

7401 ______________________________

4. Using a CMOS data book identify these 40XX series chips.

4002 ______________________________

4012 ______________________________

4077 ______________________________

4073 ______________________________

5. Explain what will happen if the supply voltage pin and the ground pin on a digital I.C. are mistakenly interchanged.

6. What does the "N" suffix stand for on a 74XXN IC?

After you complete this activity sheet, check with your instructor for any "introduction" to digital electronic breadboarding he/she might have.

ACTIVITY SHEET E 3.2

ANSWER SHEET

1.
   a) readily available for purchase
   b) low cost

2.
   a. NAND
   b. NOR
   c. AND
   d. Hex Inverter
   e. XOR

   Pin 14 = Y
   Pin 1 = X
   Pin 7 = Z

3. 7410 - 3 input NAND
   7430 - 8 input NAND
   7410 - Open collector NAND

4. 4002 - 4 input NOR
   4012 - 4 input NAND
   4077 - XOR
   4073 - 3 input AND

5. The chip will be ruined!

6. Plastic dual in-line package

INFORMATION SHEET

E 3.3

GATE SYMBOLS AND TRUTH TABLES

Positive Logic and Gate:

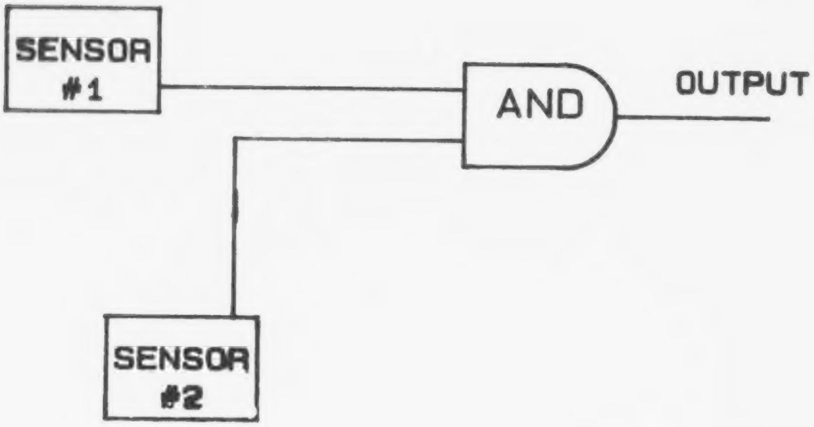
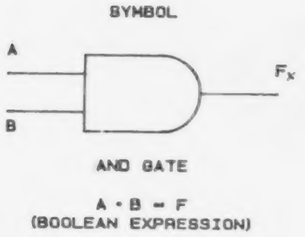


Figure E 3.3-1

Figure E 3.3-1 is an example of an AND gate used to detect the same logic from two sensors. The AND gate requires all inputs to be logic 1 for the output to yield a logic 1. AND gates are often used where two inputs have to be the same before the output changes.

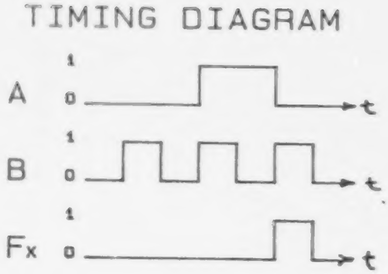
Each logic gate is unique. Each has its own symbol, truth table, Boolean expression, circuit equivalency, and chip pin-out. Consult Figure E 3.3-2 on the following page.

Positive Logic or Gate:


SYMBOL
A
B
Fx
AND GATE
A · B = F
(BOOLEAN EXPRESSION)

TRUTH TABLE

INPUT		OUT
A	B	Fx
0	0	0
0	1	0
1	0	0
1	1	1


TIMING DIAGRAM
A
B
Fx
1
0
t

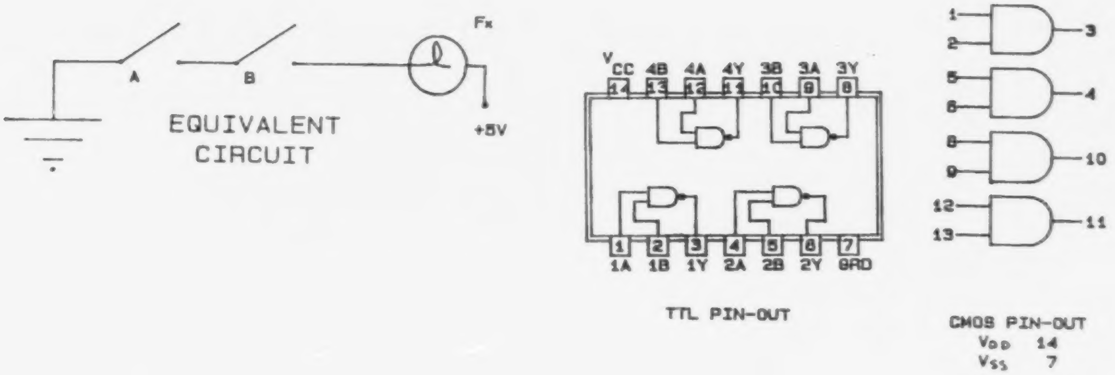

A
B
Fx
+5V
EQUIVALENT CIRCUIT
VCC 4B 4A 4Y 3B 3A 3Y
14 13 12 11 10 9 8
1 2 3 4 5 6 7
1A 1B 1Y 2A 2B 2Y GRD
TTL PIN-OUT
1 2 3
5 6 4
8 9 10
12 13 11
CMOS PIN-OUT
VDD 14
VSS 7

Figure E 3.3-2

The OR gate will yield a logic 1 output if either of its inputs has a logic 1. Figure E 3.3-2 is an example of a typical OR gate application. Note, if either problem occurs, the fan will be turned on. It will also be on if they both occur.

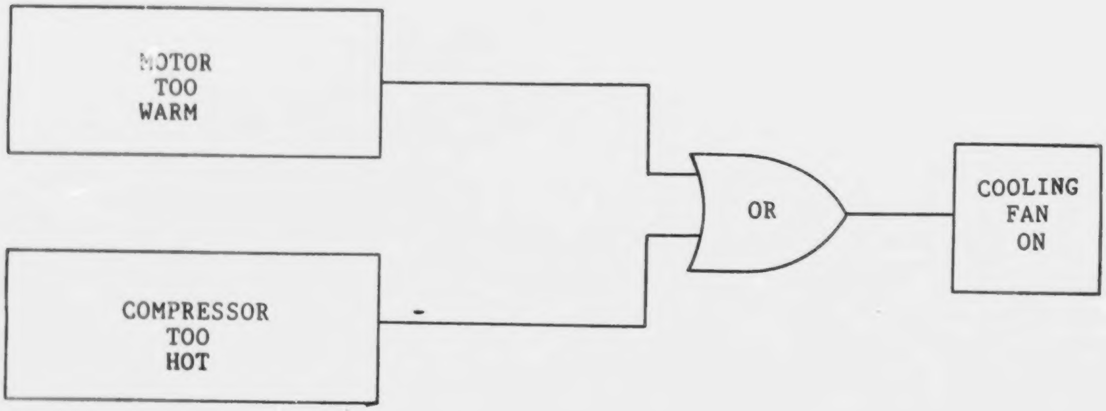
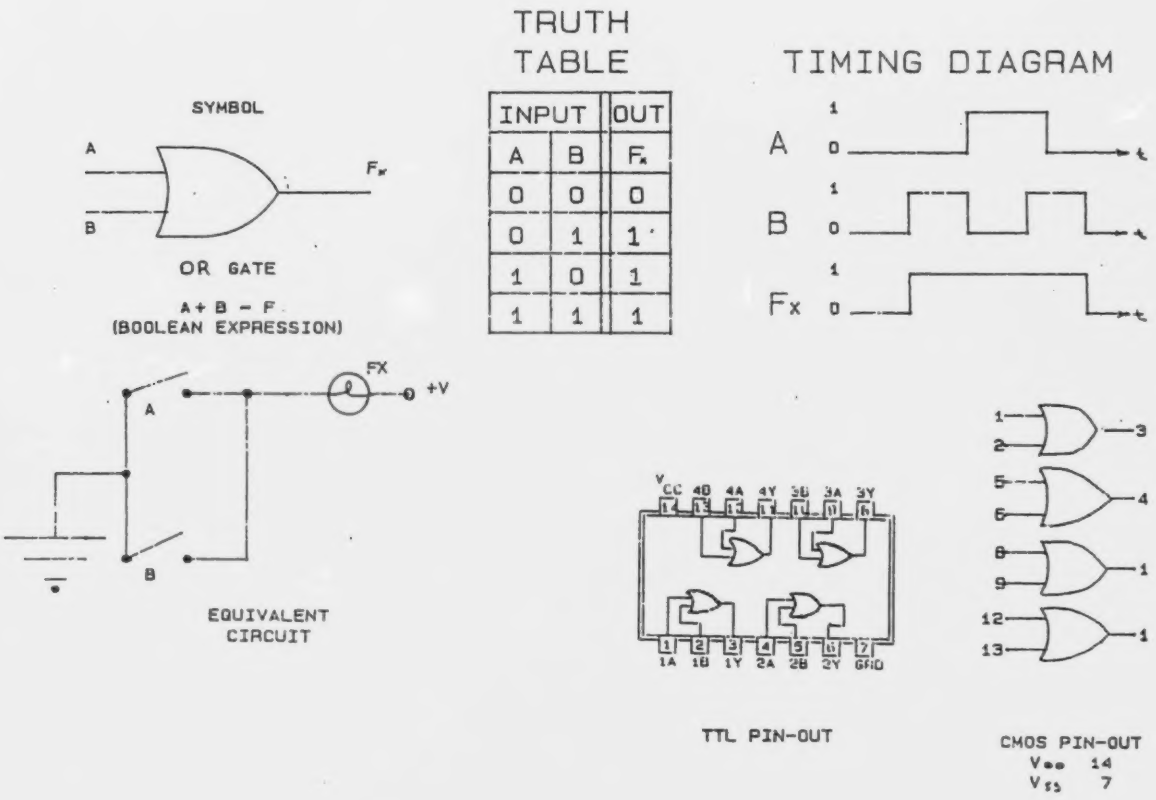

MOTOR
TOO
WARM
COMPRESSOR
TOO
HOT
OR
COOLING
FAN
ON

Figure E 3.3-3

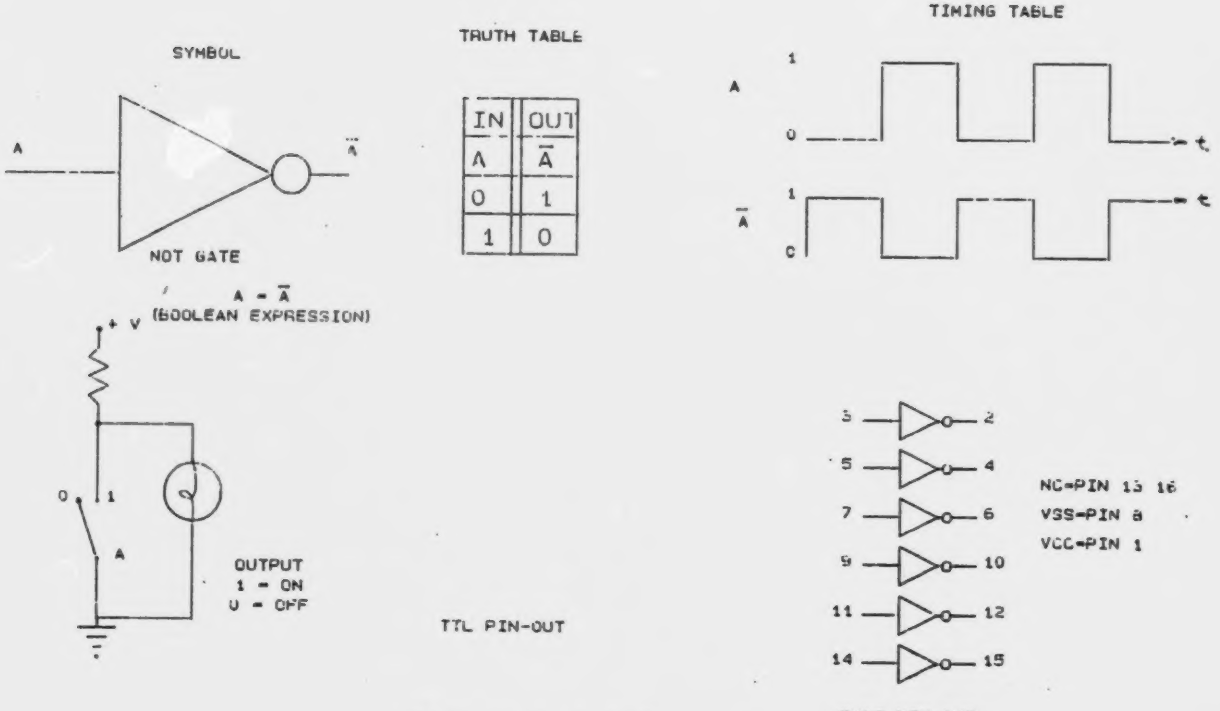

SYMBOL
A
B
Fx
OR GATE
A + B - F
(BOOLEAN EXPRESSION)
TRUTH TABLE
TIMING DIAGRAM
A
B
Fx
1
0
t
FX
+V
A
B
EQUIVALENT CIRCUIT
VCC 4B 4A 4Y 3B 3A 3Y
14 13 12 11 10 9 8
1 2 3 4 5 6 7
1A 1B 1Y 2A 2B 2Y GND
TTL PIN-OUT
1
2
3
5
6
4
8
9
12
13
CMOS PIN-OUT
VDD 14
VSS 7

INPUT		OUT
A	B	Fx
0	0	0
0	1	1
1	0	1
1	1	1

Figure E 3.3-4

Figure E 3.3-4 demonstrates the OR gate included with the Boolean expression, truth table, timing diagram, equivalent circuit and the TTL, CHOS Pin-out graphs to explain its application.

Positive Logic Inverter:

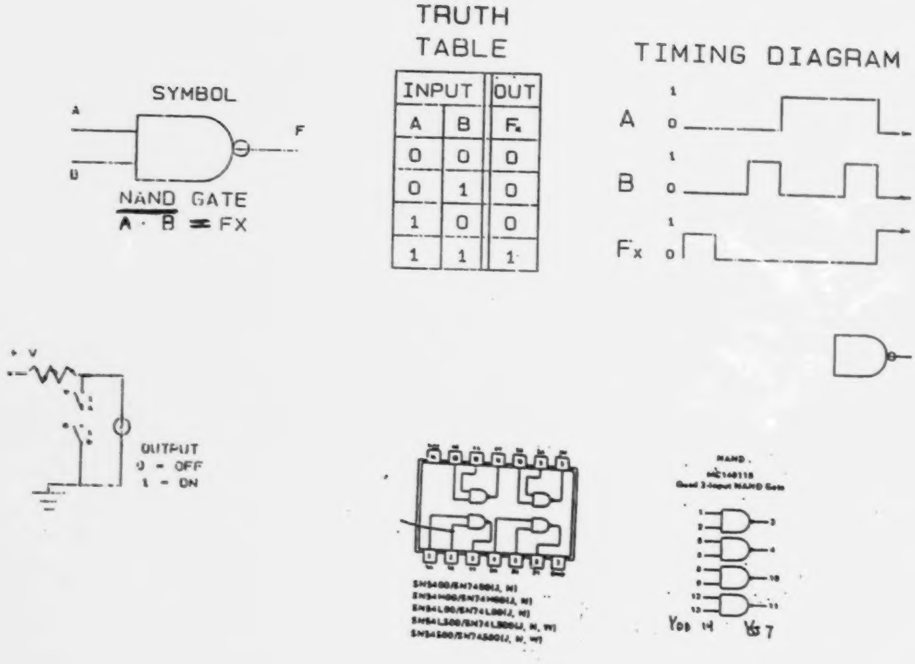

SYMBOL
A
Ā
NOT GATE
A - Ā
(BOOLEAN EXPRESSION)
TRUTH TABLE
TIMING TABLE
A
1
0
t
Ā
1
0
t
+ V
0
1
A
OUTPUT
1 - ON
0 - OFF
TTL PIN-OUT
3
2
5
4
7
6
9
10
11
12
14
15
NC-PIN 13 16
VSS-PIN 8
VCC-PIN 1
CMOS PIN-OUT

IN	OUT
A	Ā
0	1
1	0

Figure E 3.3-5

The NOT gate is most often referred to as an inverter. It is called an inverter because it takes the original logic and inverts (changes) it to the opposite state. An inverter is used when the logic at an input or output is not the logic desired. If the output of a gate is high and the design to the next device calls for a low, then an inverter is used to change the logic.

Inverters can be grouped in a service arrangement to provide propagation delay. A propagation delay is a method of increasing time between an input and an output. It occurs due to the fact that it takes a fixed period of time for logic signals to go from the input to the output. By "stringing" several inverters together you create a "delay." This technique is handy when timing is critical.

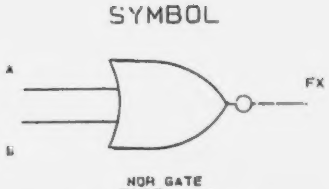

SYMBOL
A
B
F
NAND GATE
$\overline{A \cdot B} = FX$
TIMING DIAGRAM
A
B
Fx
1
0
+ V
OUTPUT
0 - OFF
1 - ON
SN5400/SN7400(J, N)
SN54H00/SN74H00(J, N)
SN54L00/SN74L00(J, N)
SN54LS00/SN74LS00(J, N, W)
SN54S00/SN74S00(J, N, W)
NAND .
MC14011B
Quad 2-Input NAND Gate
1
2
3
5
6
4
8
9
10
12
13
11
VDD 14
VSS 7

TRUTH TABLE

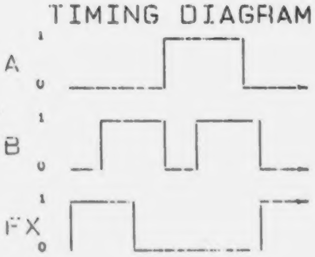
INPUT		OUT
A	B	Fx
0	0	0
0	1	0
1	0	0
1	1	1

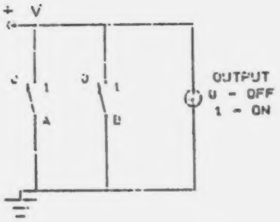
Figure E 3.3-6

A NAND gate is sometimes referred to as a "NOT AND GATE." It functions as an AND gate with an inverter on the output. The "bubble" on the output means inversion. The bar across the top of the Boolean expression indicates the gate is performing AND logic, and its output is inverted. If you study the truth table and timing diagram you may notice that a positive-logic NAND is also a negative-logic NOR, and vice-versa. In a later lesson you will see how NAND gates can be arranged to perform all of the basic logic functions.


SYMBOL
A
B
FX

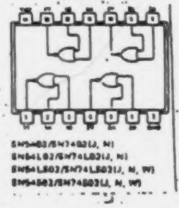
NOR GATE
$\overline{A + B} = FX$
(BOOLEAN EXPRESSION)


TIMING DIAGRAM
A
B
FX
1
0
1
0
1
0


+ V
0
1
A
0
1
B
OUTPUT
0 - OFF
1 - ON

Inputs		out
A	B	Fx
0	0	1
0	1	0
1	0	0
1	1	0

Truth Table


SN5402/SN7402(J, N)
SN54L02/SN74L02(J, N)
SN54LS02/SN74LS02(J, N, W)
SN54S02/SN74S02(J, N, W)

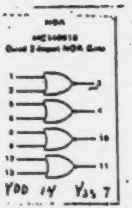
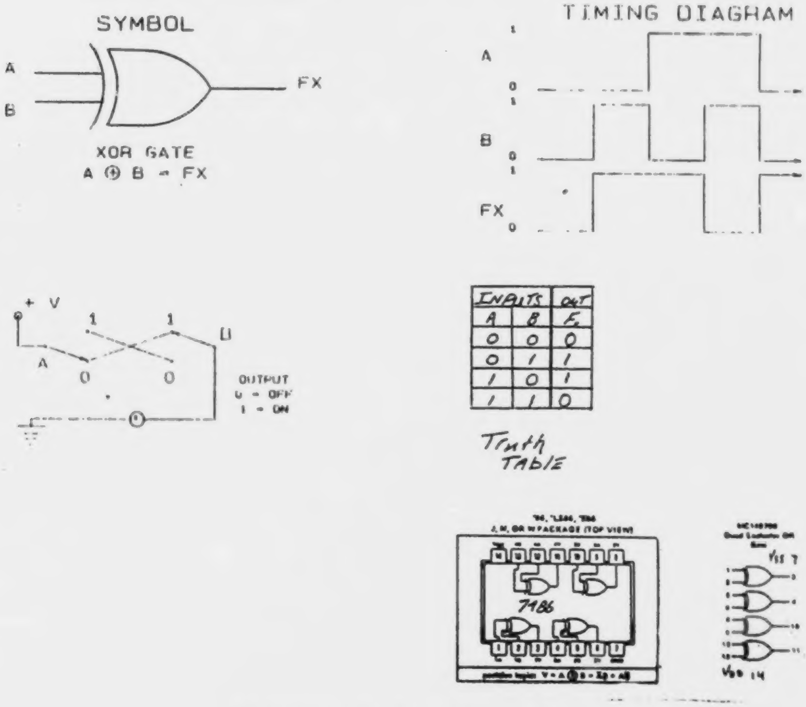

NOR
MC14001B
Quad 2-Input NOR Gate
1
2
3
5
6
4
8
9
10
12
13
11
VDD 14
VSS 7

Figure E. 3.3-7

A NOR gate is a NOT OR gate. It is nothing more than an OR gate with an inverter "bubble" on its output. The output of the NOR gate is exactly opposite that of an OR gate. The NOR circuit will yield a high output if both of its inputs are low.

INFORMATION SHEET E 3.3 CONT'D.


SYMBOL
A
B
FX
XOR GATE
A ⊕ B = FX
TIMING DIAGRAM
A
B
FX
1
0
+V
1
1
A
B
0
0
OUTPUT
0 = OFF
1 = ON
7486

INPUTS		OUT
A	B	F
0	0	0
0	1	1
1	0	1
1	1	0

Truth Table

Figure E 3.3-8

The Exclusive OR gate, XOR, is often thought of as the "either-or, but not both" gate. It will yield a high output if either of its outputs are high, but not both. XOR gates are sometimes used in digital arithmetic circuits because of this function. Another way to look at the XOR is in terms of the inputs being even or odd. If it has an odd combination of logic on its input, the output is high; however, if it has an even combination, its output is low.

There is also an XNOR gate. Its operation is opposite of the XOR. Figure E 3.3-8 shows its characteristics.

To build an XNOR, use an XOR chip and an inverter IC. The timing diagram will be exactly opposite of the XOR. Figure E 3.3-9 shows how it would be constructed.

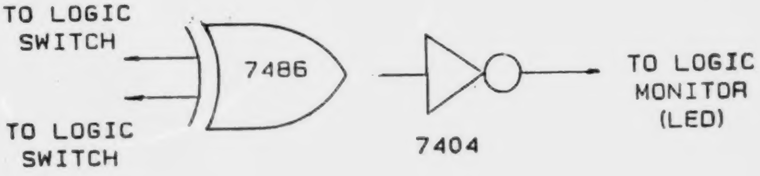

TO LOGIC SWITCH
TO LOGIC SWITCH
7486
7404
TO LOGIC MONITOR (LED)

Figure E 3.3-9

ACTIVITY SHEET

E 3.4

GATE SYMBOLS AND TRUTH TABLES

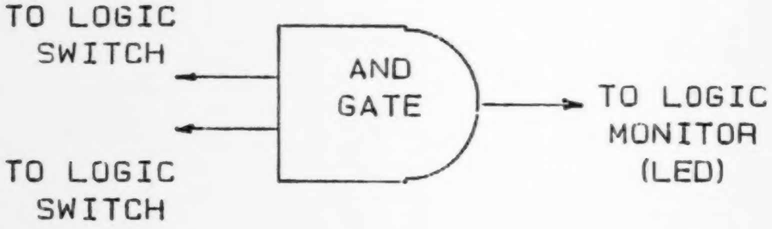
OBJECTIVE: In this activity you will verify the basic logic functions of each gate.

EQUIPMENT AND MATERIAL REQUIRED:

1. Logic trainer
2. TTL ICs 1-7400, 1-7402, 1-7404, 1-7408, 1-7432, and 1-7486.
3. CMOS ICs (If your instructor is not using this logic family skip these.) 1-4081B, 1-4071B, 1-4049B, 1-4011B, 1-4001B.

PROCEDURES: At the end of this activity sheet there is an area marked-"Tables, Charts, Graphs, etc." - at this location draw and label your symbols and truth tables.

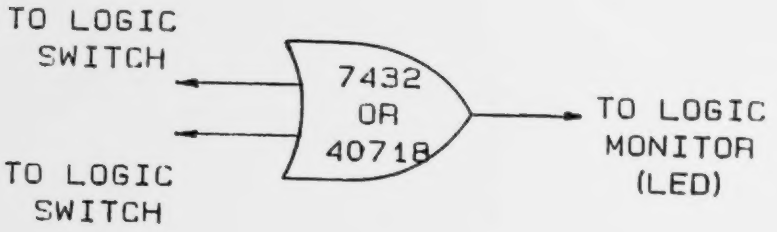
1. Breadboard this circuit on your logic trainer. Check IC pin-out for proper connections.



2. Construct a two input truth table. (Label inputs and output.) Also draw gate logic diagram.
3. Apply logic to each input as indicated by truth table and record output. (Light on equals Logic 1. Light off equals Logic 0.)
4. Complete the truth table.
5. Connect logic to each gate in the IC and verify that it works.

ACTIVITY SHEET E 3.4 CONT'D.

6. Remove the AND gate IC from your breadboard, and connect the OR gate IC as drawn below.


TO LOGIC SWITCH
7432
OR
4071B
TO LOGIC SWITCH
TO LOGIC MONITOR (LED)

7. In the area provided for tables and graphs, construct a two input truth table. (Label inputs and outputs.) Draw logic gate symbol.

8. Apply the logic indicated by the truth table and record the output.

9. Complete table.

10. Verify that each gate in the IC works.

11. Repeat steps 6-10 for the IC inverter. (7404 or 4049B)

12. Repeat steps 6-10 for the NAND gate IC. (7400 or 4011B)

13. Repeat steps 6-10 for the NOR gate IC. (7402-4001B)

14. Repeat steps 6-10 for the XOR gate IC. (7486-4070B)

15. Using the XOR circuit of step 14 add an inverter to its output and repeat steps 7-9. See Figure E 3.4-1.

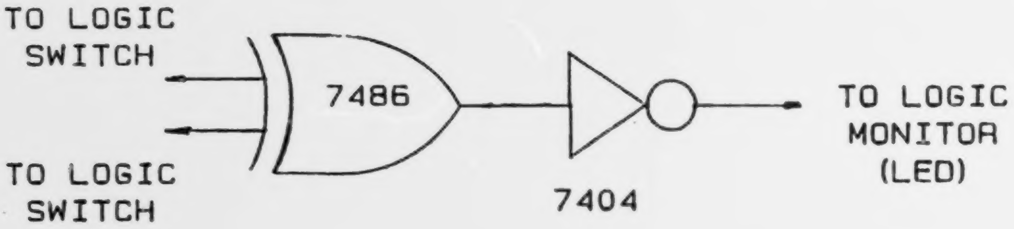

TO LOGIC SWITCH
7486
TO LOGIC SWITCH
7404
TO LOGIC MONITOR (LED)

Figure E 3.4-1

ACTIVITY SHEET E 3.4 CONT'D.

CHARTS, GRAPHS, TABLES, and DIAGRAMS

INFORMATION SHEET

E 3.5

MULTIPLE-INPUT GATES

There are many applications which require more than two logic inputs. A 3-input AND gate can be configured from two 2-input AND gates. Figure E 3.5-1 is an example of this process.

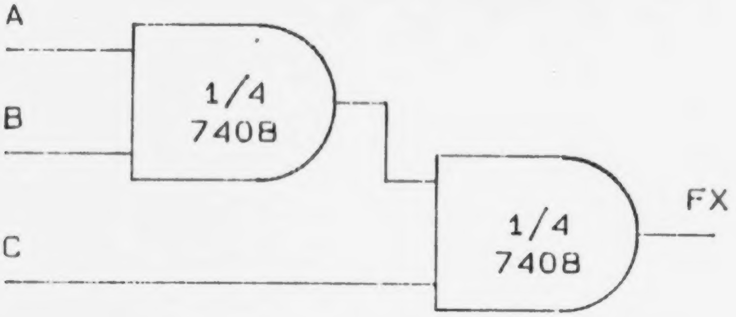


Figure E 3.5-1

Remember the typical IC gate chip is a quad unit; that is, it has four separate z-input gates in each package.

The truth table for a 3-input gate is longer than one for a 2-input. This is due to the number of different switch or logic input combinations. The number of combinations can be calculated by raising the base of 2 by the number of inputs. An example of this is as follows: 3 inputs--2^3=8 combinations. 4-input--2^4=16 combinations, and 5 input--2^5=32 combinations. Figure E 3.5-2 is an example of a 3-input truth table. Note the 3-input AND gate still has the same logic. The Boolean expression for a 3-input AND is, $A \cdot B \cdot C = F_x$. The logic symbols looks like Figure E 3.5-3.

A	B	C		F_x
0	0	0		0
0	0	1		0
0	1	0		0
0	1	1		0
1	0	0		0
1	0	1		0
1	1	0		0
1	1	1		1

Figure E 3.5-2

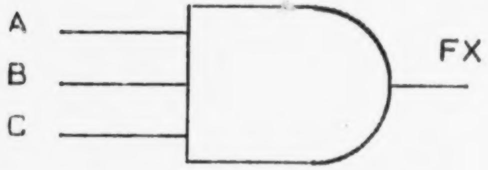


Figure E 3.5-3

A gate with any number of inputs can be built from 2-input gates. Figure E 3.5-4 is an example of a 4-input OR gate. Figure E 3.5-5 is a 4-input truth table for an OR gate.

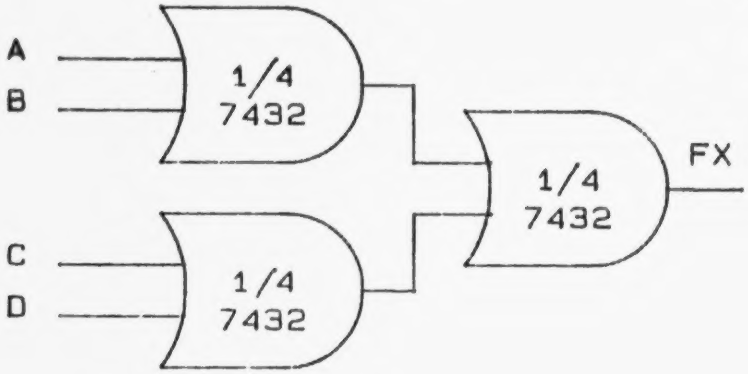


Figure E 3.5-4

Notice that the inputs in the table are binary numbers starting at zero and going to 15. Study the truth table and note the arrangement of ones and zeros. Can you see any pattern? Use this pattern to construct your truth tables. (Figure E 3.5-5)

ACTIVITY SHEET E 3.5 CONT'D.

A	B	C	D	Fx
0	0	0	0	0
0	0	0	1	1
0	0	1	0	1
0	0	1	1	1
0	1	0	0	1
0	1	0	1	1
0	1	1	0	1
0	1	1	1	1
1	0	0	0	1
1	0	0	1	1
1	0	1	0	1
1	0	1	1	1
1	1	0	0	1
1	1	0	1	1
1	1	1	0	1
1	1	1	1	1

Figure E 3.5-5

Not all multiple input gates have to be constructed from 2-input units. The manufacturers have provided I.C.'s with multiple input gates. The 7410 is a 3-input NAND, and the 7430 is an 8-input NAND. Check manufacturers' data books see what gate chips are available.

ACTIVITY SHEET

E 3.6

MULTIPLE-INPUT GATES

OBJECTIVE: This activity sheet will require you to build multiple-input gates from 2-input gates. You will also be required to construct truth tables for these multiple input gates.

EQUIPMENT AND MATERIAL REQUIRED:

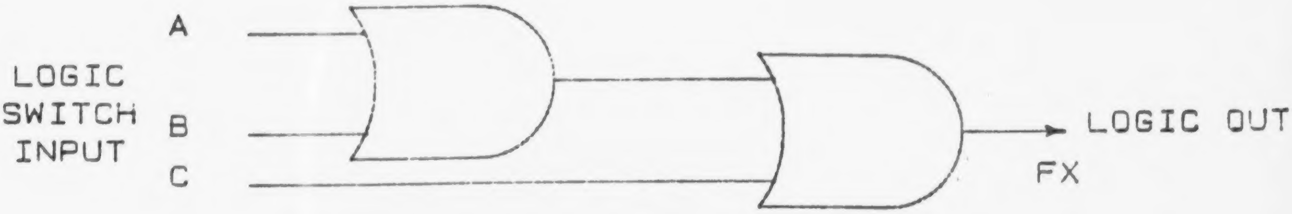
Digital Logic Trainer

The following Digital I.C.

	2- 7400's		2- 4011's
TTL	1- 7402		1- 4001
	1- 7432	CMOS	1- 4071

PROCEDURE:

1. Breadboard this circuit.



2. In the area marked "Graph, Charts, and Tables," construct a 3-input truth table. Also write the Boolean expressions and draw the logic symbol for a input OR gate.

3. Using the truth-table verify the operation of a 3-input OR gate.

4. In the area marked "Graphs, Charts, and Tables" draw the schematic diagram for a 5-input NAND gate. Also construct a truth table, draw the logic symbol and write the Boolean expression for this gate.

5. Breadboard the circuit, apply the appropriate logic on the inputs and verify the operation of a 5-input NAND gate.

6. Repeat steps 4-5, but for a 4-input NOR gate.

7. When you have finished, show your tables and symbols to your instructor, and check for a further activity.

ACTIVITY SHEET E 3.6 CONT'D.

CHARTS, GRAPHS, TABLES, and DIAGRAMS

Multiple - Input Gates

PROGRAM: ELECTRONICS

TASK: BOOLEAN LOGIC

TASK #: E 3.7

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ________________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ________________

PERFORMANCE OBJECTIVE:

Verify basic Boolean expressions using truth tables and logic gates.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out of 8 points or 75% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 8 points or 75% and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

BOOLEAN LOGIC

E 3.7

CRITICAL ITEMS	ITEMS TO BE OBSERVED OR CHECKED	RATING YES/NO	
1.	Was the circuit wired according to the schematic?	Y	N
*2.	Does the circuit function properly?	Y	N
*3.	Was necessary data recorded?	Y	N
4.	Was the correct equipment used?	Y	N
5.	Was the equipment used properly?	Y	N
*6.	Were safety precautions followed?	Y	N
*7.	Was equipment returned to proper storage area?	Y	N

TOTAL POINTS POSSIBLE ___

POINTS NEEDED FOR MASTERY ___

SCORE ___

EXAM E 3.8

DIRECTIONS:

The purpose of this exam is to determine whether or not you understood the information on Basic Boolean Expressions, Truth Tables, and Logic Gates. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on your ANSWER SHEET. DO NOT WRITE ON THIS TEST!!!! To master this exam you must answer 16 out of 20 items correctly, 80%.

EXAM E 3.8 CONT'D.

1. A 7400 contains which of the following gates ____________.

   A. Quad AND
   B. Quad NAND
   C. Quad NOR
   D. Quad OR

2. Which troubleshooting device allows you to "look" at the logic on each pin?

   A. Pulser
   B. V.O.M.
   C. Logic clip
   D. LED

3. When using TTL logic, a valid logic low is, (positive logic) ______________.

   A. between ground and 2.4 volts
   B. between ground and .8 volts
   C. between negative 2.4 volts and ground
   D. none of the above
   E. all of the above

4. When referring to negative logic, _________________.

   A. a logic one would be a plus 5 volts
   B. a logic one would be a negative voltage
   C. a logic one would be between +2.4 volts and +5 volts
   D. none of the above

5. Which gate could be considered the either/or gate?

   A. AND
   B. NOT
   C. NAND
   D. XOR
   E. None of these

6. Which gate must have all inputs high before it yields a high output?

   A. AND
   B. NAND
   C. XNOR
   D. None of these

7. Which gate could be thought of as switches in series?

A. AND
B. NAND
C. NOR
D. XOR

8. Which gate will yield a high logic if any of its inputs are high?

A. NOR
B. NAND
C. AND
D. OR

9. Which gate is used to change logic?

A. OR
B. NOR
C. AND
D. NOT

Match the following Boolean expressions to the proper gate.

10. AND Gate:

A. $A+B=Fx$
B. $A\cdot=Fx$
C. $A\cdot B=Fx$
D. $A \oplus B=Fx$

11. OR Gate:

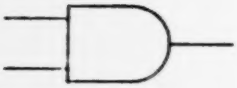
A. $A \oplus B = Fx$
B. $A = A$
C. $A + B = Fx$
D. $A \oplus B = Fx$

12. NOT Gate:

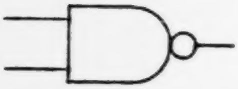
A. $A + B = Fx$
B. $A \cdot = Fx$
C. $A + B = Fx$
D. $A = A$

13. NAND Gate:

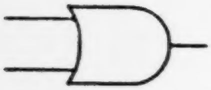
A.



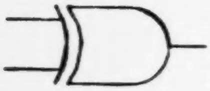
B.



C.

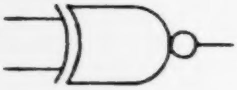


D.

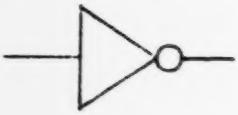


14. XOR Gate:

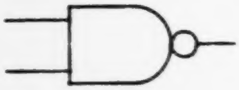
A.



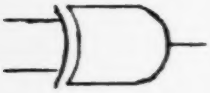
B.



C.

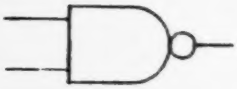


D.

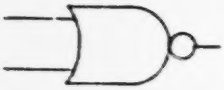


15. NOT Gate:

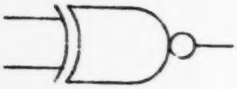
A.

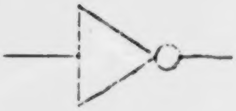


B.

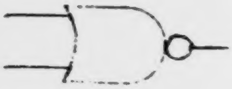


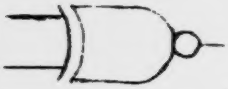
C.

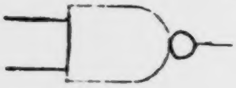


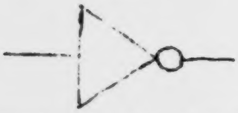
D. 

16. NOR Gate:

A. 

B. 

C. 

D. 

17. A 4-input truth table would have _____ input combinations.

A. 2^3

B. 2^2

C. 2^4

D. 2^5

18. With a quad 2-input gate chip you can build which of the following multiple input gates:

A. two 3-input gates
B. one 4-input gate
C. one 5-input gate
D. all of the above

19. A 5-input truth table has _____ input combinations.

A. 64
B. 16
C. 18
D. None of these

20. A 7410 is an example of a _____.

A. 3-input OR gate
B. 3-input NAND Gate
C. 4-input OR Gate
D. None of these

EXAM KEY E 3.8

1. B
2. C
3. B
4. B
5. E (XOR is either/or but not both)
6. A
7. A
8. D
9. D
10. B
11. C
12. D
13. B
14. D
15. D
16. A
17. C
18. D
19. D
20. B

ELECTRONICS

ANALYZING DIGITAL ELECTRONIC CIRCUITS

E 4: NAND LOGIC

TASK: Using NAND logic, construct basic logic circuits from Boolean expressions.

PURPOSE: Boolean algebra is a system of expressing logic in mathematical terms. It is a tool used by design engineers. It is also a tool which can be used by the electronics technician to aid in troubleshooting digital logic circuits. This learning guide will introduce the basics of Boolean algebra and Karnaugh maps. These tools will be used as an aid to better understand basic combinational logic circuits.

OBJECTIVE: Given access to all necessary tools and equipment, you will use NAND logic and construct basic logic circuits from Boolean expressions. To master this task you must score 80% on a written exam and a performance checklist.

ESTIMATED CLASS TIME: 12 HOURS

NAND LOGIC

LEARNING STEPS

E 4

READ: Information Sheet E 4.1, and "DeMorgan's Laws and NAND Logic."

READ: Information on NAND logic from the following resource list.

COMPLETE: Activity Sheet E 4.2 "NAND Logic."

READ: Information on "Boolean Algebra and K-Maps" in Information Sheet E 4.3

READ: Information on Boolean algebra and K-maps from the following resource list.

COMPLETE: Activity Sheet E 4.4 "Boolean Algebra and K-Maps."

REVIEW: All material covered in this learning guide.

COMPLETE: Performance Checklist E 4.5. Contact your instructor.

COMPLETE: Written Exam E 4.6. Contact your instructor.

NAND LOGIC

RESOURCES

E 4

1. *CMOS DATA MANUAL* (Motorola).
2. Brey, *DIGITAL ELECTRONICS* (Bobbs-Merrill, 1984).
3. Tokheim, *DIGITAL ELECTRONICS TEXT* AND *ACTIVITY MANUAL* (McGraw-Hill, 1984).
4. Tocci, *DIGITAL SYSTEMS* (Prentice-Hall, 1984).
5. *DIGITAL TECHNIQUES STUDENT WORKBOOK* (Heath Co., 1981).
6. Williams, *DIGITAL TECHNOLOGY* (SRA, 1982). 2nd Ed.
7. Hall, *MICROPROCESSORS* AND *DIGITAL SYSTEMS* (McGraw-Hill, 1983). 2nd Ed.
8. Texas Instrument *TTL DATA MANUAL*.

INFORMATION SHEET

E 4.1

DEMORGAN'S LAW AND NAND LOGIC

DeMorgan's laws are used to simplify Boolean expressions, and as an aid for explaining NAND logic. DeMorgan's laws relate to the Boolean expression in the following manner:

$\overline{A + B} = Fx = \bar{A} + \bar{B} = Fx$, and $\bar{A} + \bar{B} = Fx = \overline{A + B} = Fx$.

Stated another way it says, "break the bar and change the operation." The long bar, "————————," refers to an inverted output and the short bars, "—," refer to inverted inputs. In the first example, the NAND function " ————" can be performed by using an OR gate with inverters on its inputs. This can be represented symbolically by Figure E 4.1-1. This can also be proven by constructing a truth table. (See Figure E 4.1-2)

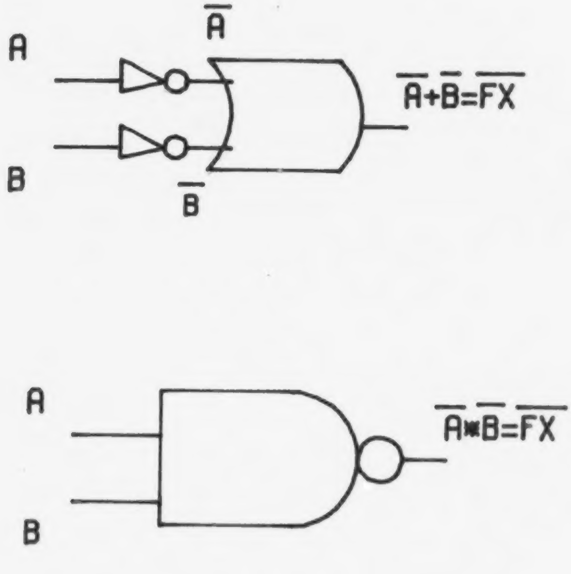

A
$\overline{A}$
$\overline{A}+\overline{B}=\overline{FX}$
B
$\overline{B}$
A
$\overline{A}*\overline{B}=\overline{FX}$
B

Figure E 4.1-1

By using inverters, any gate can be made from any other gate. This can be proven in lab. Later in this learning guide, you will prove De Morgan's laws.

Truth Table

A	B	A	B	Fx
0	0	1	1	1
0	1	1	0	1
1	0	0	1	1
1	1	0	0	0

Figure E 4.1-2

DeMorgan's laws make it possible to save costs. An example will make this point. Let's say the design calls for the following logic, NAND and OR. Without DeMorgan's laws there would have to be two I.C.'s, 1-7400 NAND and 1-7432 OR. The space on the printed circuit card would be taken up by two 14-pin chips. By using DeMorgan's laws the logic could be implemented with 1-7400 quad NAND gate chip. Figure E 4.1-3 shows how this would look.

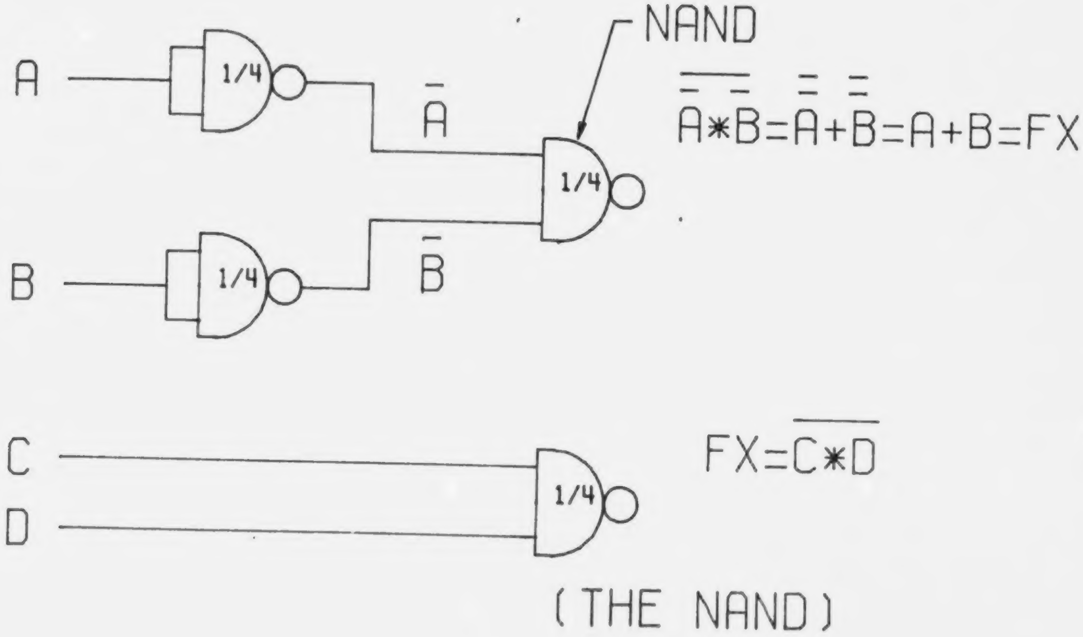

A
B
1/4
1/4
1/4
$\bar{A}$
$\bar{B}$
NAND
$\overline{\bar{A}*\bar{B}}=\bar{\bar{A}}+\bar{\bar{B}}=A+B=FX$
C
D
1/4
$FX=\overline{C*D}$
(THE NAND)

Figure E 4.1-3

Note that NAND gates with their inputs tied together can be used as inverters. If you study the diagram you will see that it only took 1 set of 4 NAND gates to perform the NAND function, C x D = Fx, and a NAND with inverted inputs to perform the OR function, A + B = Fx. The gate marked "NAND" is still performing NAND logic; that is why its output is labeled A x B; however, when you break the bar, A + B, the operation changes. The new idea is the double inversion bars, "=" this is saying, "Not - A, Not - A," which is the same thing as saying "A." Anytime there is a double inversion the letter reverts to its original input condition with no inversion. The over-all output is OR logic, which is what the design called for.

Figure E 4.1-4 is an example of NAND logic. Every basic logic function can be performed using only NAND gates.

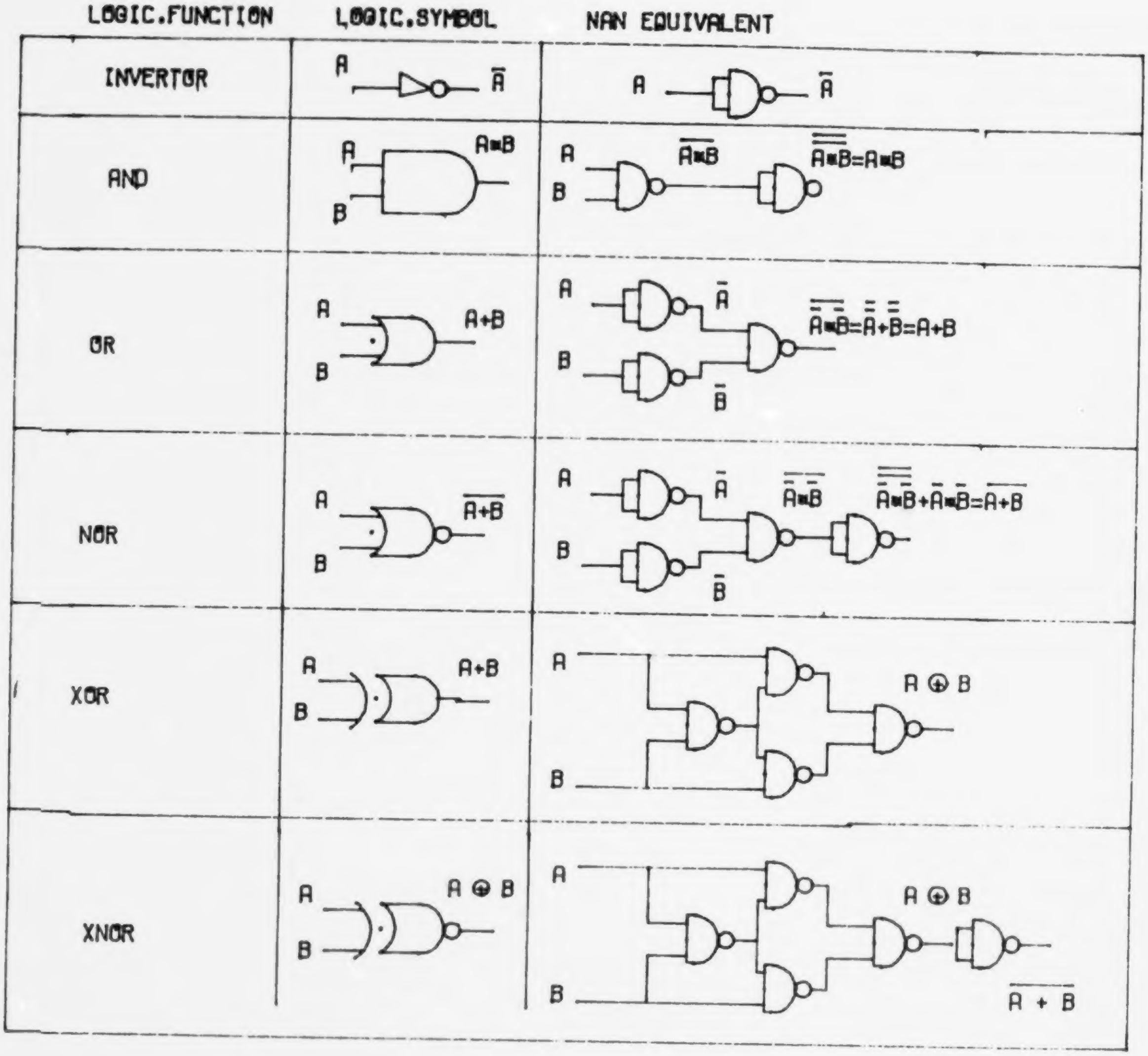

LOGIC.FUNCTION
LOGIC.SYMBOL
NAN EQUIVALENT
INVERTER
A
$\overline{A}$
A
$\overline{A}$
AND
A
B
A■B
A
B
$\overline{A■B}$
$\overline{\overline{A■B}}$=A■B
OR
A
B
A+B
A
B
$\overline{A}$
$\overline{B}$
$\overline{\overline{A}■\overline{B}}$=$\overline{\overline{A}}$+$\overline{\overline{B}}$=A+B
NOR
A
B
$\overline{A+B}$
A
B
$\overline{A}$
$\overline{B}$
$\overline{\overline{A}■\overline{B}}$
$\overline{\overline{\overline{A}■\overline{B}}}$+$\overline{A}$■$\overline{B}$=$\overline{A+B}$
XOR
A
B
A+B
A
B
A ⊕ B
XNOR
A
B
A ⊕ B
A
B
A ⊕ B
$\overline{A + B}$

Figure E 4.1-4

NAND gates are not the only gate you can use to implement other logic. The NOR will also work to implement any other logic gate. As a technician you should be aware of NAND or NOR logic so that you recognize it on a schematic diagram.

ACTIVITY SHEET

E 4.2

NAND LOGIC

OBJECTIVE: After completing this activity you should be able to use DeMorgan's laws to build any logic gate using only z-input NAND gates. You should also be familiar with what is called "bubble" logic.

EQUIPMENT AND MATERIALS:

1 - logic trainer
2 - Quad 2 - input NAND chips
(7400 TTL's or 4011 CMOS)

PROCEDURE:

1. In the area of this activity sheet marked "Charts, Graphs, and Diagrams," record all data on diagrams called for.

2. Implement the OR function using only NAND gates.

   Follow this example:

   a) A + B A x B equals NAND with inverted inputs

   b) Draw circuit diagram: (See Figure E 4.2-1)

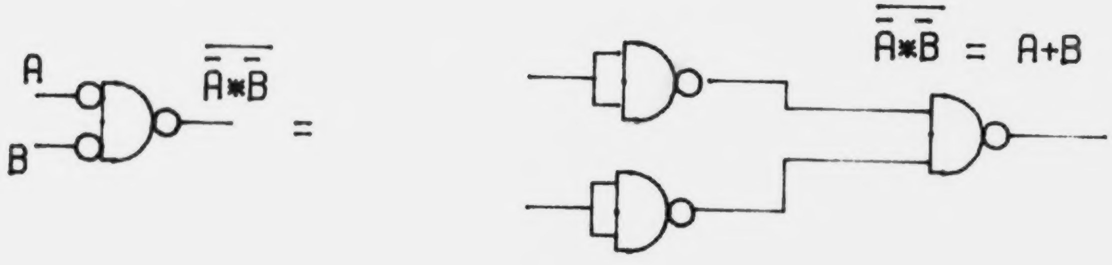

A
B
$\overline{\bar{A}*\bar{B}}$
=
$\overline{\bar{A}*\bar{B}} = A+B$

Figure E 4.2-1

(Note: I have drawn the circuit in two different ways. On the left I have used what is referred to as "bubble" notation, meaning the inverters are drawn as bubbles rather than as NAND gates with the inputs tied together. This

ACTIVITY SHEET E 4.2 CONT'D.

notation means the same thing, but it is much easier to draw. Either of these methods may be used.)

c) Draw a truth table. (See Figure E 4.2-2)

A	B	A	B	Fx
0	0	1	1	
0	1	1	0	
1	1	0	0	

Figure E 4.2-2

d) Breadboard the circuit using only NAND gates.

e) Apply logic from truth table and record output in truth table.

3. Repeat steps a - e for the following logic functions.

   AND, NOR, XOR, and XNOR

4. When you have completed this activity, it should be clear that you can perform any logic function using only NAND gates.

5. Check with your instructor to see if he/she wants you to perform the activity a second time using "NOR logic."

ACTIVITY SHEET

E 4.2

CHARTS, GRAPHS, TABLES AND DIAGRAMS

INFORMATION SHEET

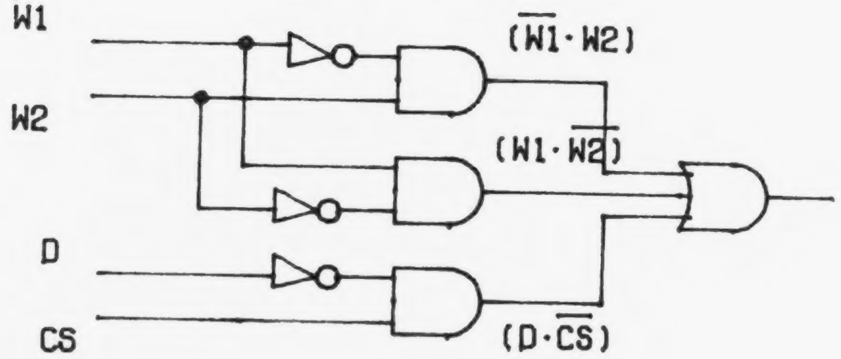
E 4.3

BOOLEAN ALGEBRA AND K-MAPS

Boolean algebra is a system of expressing logic in mathematical terms. It was conceived by George Boole. K-Map is short for Karnaugh mapping. Both techniques are used by design engineers to simplify complicated logic problems. As an electronics technician you may never have to use either of these, but if you are familiar with their basics it may someday aid you on the job. Probably the best way to explain these two techniques is by example. When considering this example, refer to Figures E 4.3-1 and E 4.3-2, which list some rules for Boolean algebra and examples of Karnaugh maps.

PROBLEM: Simple burglar alarm for an apartment.

Points to monitor: two windows, a door, and a control switch for entry. Conditions - of Control switch (CS is closed door may be opened with no alarm) If both windows are opened at the same time (for ventilation), there is no alarm. If these conditions are not met, an alarm will sound. The procedure will be as follows: (1) construct a truth table listing all conditions. (2) write a Boolean expression from the truth table. (3) Simplify by using a K-map. (4) Draw the logic diagram of the simplified expression. On the truth table a "0" will represent window closed, door closed, CS = 1" no alarm. A "1" will represent window open, door open, CS= "1," alarm ON.



Truth table showing inputs and outputs

W_1	W_2	D	C_S	Alarm
0	0	0	0	0
0	0	1	0	1
0	0	1	1	0*
0	1	0	0	1
0	1	0	1	1*
0	1	1	0	1*
0	1	1	1	1*
1	0	0	0	1*
1	0	0	1	1*
1	0	1	0	1*
1	1	0	0	0
1	1	0	1	0
1	1	1	0	1*
1	1	1	1	0

(Window is open)

(Unsimplified Boolean Expression)

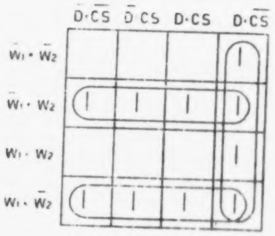
$(\overline{W1}x\overline{W2}xDx\overline{CS}) + (\overline{W1}xW2x\overline{D}x\overline{CS}) + (\overline{W1}xW2x\overline{D}xCS) + (\overline{W1}xW2xDx\overline{CS}) +$
$(\overline{W1}xW2xDxCS) + (\overline{W1}x\overline{W2}x\overline{D}x\overline{CS}) + (W1x\overline{W2}x\overline{D}xCS) + (W1x\overline{W2}xDx\overline{CS}) +$
$(W1x\overline{W2}xDxCS) + (W1xW2xDx\overline{CS}) = Fx$

(Simplified Boolean Expression)

$(Dx\overline{CS}) + (\overline{W1}xW2) + (W1x\overline{W2}) =$
Fx (Alarm)

SIMPLIFIED BOOLEAN EXPRESSION

$(D\cdot\overline{CS})\cdot(\overline{W_1}\cdot W_2)\cdot(W_1\ \overline{W_2})=Fx$

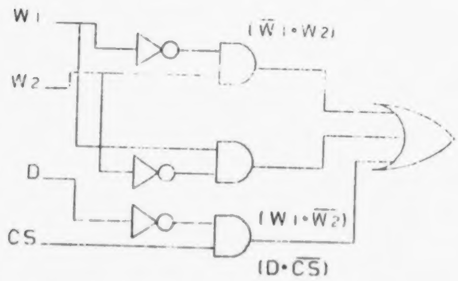


$\overline{D}\cdot\overline{CS}$
$\overline{D}\ CS$
$D\cdot CS$
$D\cdot\overline{CS}$
$\overline{W_1}\cdot\overline{W_2}$
$\overline{W_1}\cdot W_2$
$W_1\cdot W_2$
$W_1\cdot\overline{W_2}$

	$\overline{D}\cdot\overline{CS}$	$\overline{D}\ CS$	$D\cdot CS$	$D\cdot\overline{CS}$
$\overline{W_1}\cdot\overline{W_2}$				1
$\overline{W_1}\cdot W_2$	1	1	1	1
$W_1\cdot W_2$				1
$W_1\cdot\overline{W_2}$	1	1	1	1

(4 VARIABLE K-MAY)

(4 variable K-Map)



W_1
W_2
D
CS
$(\overline{W_1}\cdot W_2)$
$(W_1\cdot\overline{W_2})$
$(D\cdot\overline{CS})$

SIMPLIFIED LOGIC DIAGRAM

(Simplified Logic Diagram)

All of the expressions in this example have been what are called Minterm Boolean expressions. Another name for this form is the Sum of Products. Example - $(A \cdot B) + (C \cdot D) = Fx$ is a "Sum of Products." The OR operation is a sum operation and the AND operation is a "product." The MAXTERM is another form of Boolean expression. It is sometimes referred to as the "Product of sums." $(A + B) \cdot (C + D) = Fx$ is an example of a product of sums or a maxterm expression.

This information sheet has covered only the very basics of K-maps and Boolean Algebra. It has shown only one example of how it may be used. There are many excellent reference books on these subjects. Check with your instructor for further information if you are interested or feel the need to know more.

INFORMATION SHEET E 4.3 CONT'D.

BASIC BOOLEAN IDENTITIES

1. $A = A$ Double complement (Even number of inversions will cancel)

2. $A \cdot 0 = 0$ (AND gate with one input low yields a low output)

3. $A \cdot 1 = A$ (AND gate with input high will "pass" whatever logic is on input A)

4. $A + 0 = A$ (OR gate with input low will "pass" whatever logic is on input A)

5. $A + 1 = 0$ (OR gate with one input high yields a high output)

6. $A \cdot A = 0$ (one input cannot have different logic at the same time)

7. $A \cdot B = B \cdot A$ (Commutative Law)

8. $A + B = B + A$ (Commutative Law)

9. $A \cdot A = A$ (Redundancy - only one of each input is needed)

10. $A + A = A$ (Redundancy - only one of each input is needed)

11. $A \cdot (B \cdot C) = (A \cdot B) \cdot C = A \cdot B \cdot C$ (Associative Law)

12. $A + (B + C) = (A + B) + C$ (Associative Law)

13. $A \cdot (B + C) = (A \cdot B) + (A \cdot C)$ (Distributive Law)

14. $A + (B \cdot C) = (A + B) \cdot (A + C)$ (Distributive Law)

15. $A + (B \cdot C) = A$ (Simplification - drop longer term, keep the shorter term)

16. $A \cdot (A + B) = A$ (Simplification - drop longer term, keep the shorter term)

17. $A + (A \cdot B) = A + B$ (Drop the complement)

18. $(A \cdot B) + (A \cdot B) + (A \cdot B) = A + B$

INFORMATION SHEET E 4.3 CONT'D.

BOOLEAN ALGEBRA AND K-MAPS

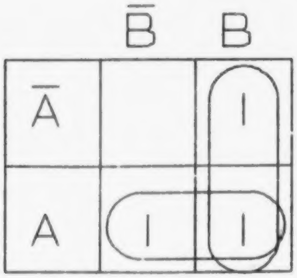


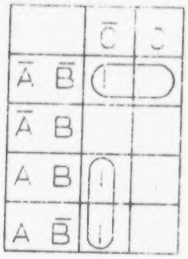
Figure E 4.3-2

The 1's are grouped in 2's and 4's. Each loop represents a simple term. A and A cancel in the vertical loop. B and B cancel in the horizontal loop. The final expression is A + B = Fx

---

Typical 3-input Boolean Expression

A·B·C + A·B·C + A·B·C + A·B·C= Fx



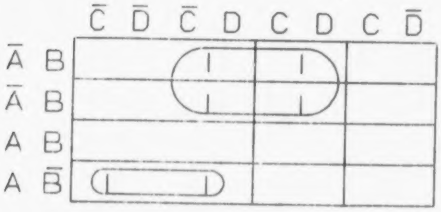
Top loop: C and C drop leaving A·B
Bottom loop: B and B drop leaving A·C

3 variable map

Simplified expression is A·B + A·C = Fx

(A·B·C·D·) + (A·B·C·D·) + (A·B·C·D·) + (A·B·C·D·) + (A·B·C·D·) +

(A·B·C·D·) = Fx



Top Loop: C and C B and B drop
Left with A·D

Bottom Loop: D and D drop
Left with, A·B·C

Final simplified expression is
A·D + A·B·C = Fx

ACTIVITY SHEET

E 4.4

BOOLEAN ALGEBRA AND K-MAPS

OBJECTIVE: After completing this activity you should be able to convert a Boolean expression to a truth table, draw Karnaugh maps, and simplify a Boolean expressions.

EQUIPMENT AND MATERIALS:

Logic trainer
2 3-input AND gates
2 hex inverter chips
1 7432 QUAD OR and 1 7408 QUAD AND

PROCEDURE:

1. In the area marked, "Charts, Graphs, Tables and Diagrams," construct a truth table for this Boolean expression: $(A\cdot B\cdot C) + (A\cdot B\cdot C) + (A\cdot B\cdot C) + (A\cdot B\cdot C) + (A\cdot B\cdot C) = Fx$.
2. Plot 1's on a 3-variable K-map (Hint: Think of the map as a cylinder, which may wrap in either or both directions).
3. Eliminate variables whose complements appear within loops, and write the simplified Boolean expression.
4. Draw the logic diagram for the Boolean expression in step number 1.
5. Breadboard the circuit and verify the truth table. (Beware of wiring errors.)
6. Draw the logic diagram for the simplified Boolean expression.
7. Breadboard the simplified circuit and verify the truth table.
8. Is there any savings gained by using the K-maps and Boolean algebra to simplify?

ACTIVITY SHEET E 4.4

CHARTS, GRAPHS, TABLES AND DIAGRAMS

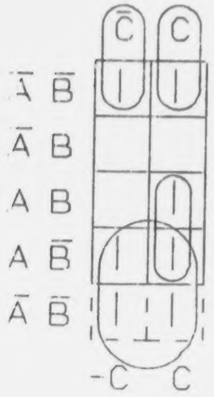
ACTIVITY SHEEET E 4.4

ANSWER SHEET

1.

INPUTS			OUTS	
A	B	C	Fx	
0	0	0	1	$(\bar{A} \cdot \bar{B} \cdot \bar{C})$
0	0	1	1	$(\bar{A}\ \bar{B} \cdot C)$
0	1	0	0	
0	1	1	0	
1	0	0	1	$(A\ \bar{B}\ \bar{C})$
1	0	1	1	$(A\ \bar{B}\ C)$
1	1	0	0	
1	1	1	1	$(A\ B\ C)$

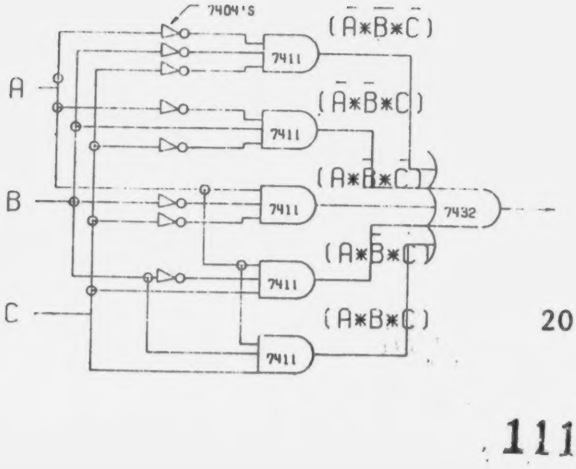
2.



$\bar{C}$
C
$\bar{A}\ \bar{B}$
$\bar{A}$ B
A B
A $\bar{B}$
$\bar{A}\ \bar{B}$
1
1
1
1
1
-C
C

3. $\overline{B} + A\ C = Fx$

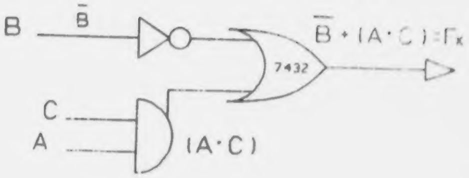
4.



7404'S
$(\bar{A}*\bar{B}*\bar{C})$
7411
A
$(\bar{A}*\bar{B}*C)$
7411
$(A*\bar{B}*\bar{C})$
B
7411
7432
$(A*\bar{B}*C)$
7411
C
$(A*B*C)$
7411

5. See Instructor

6.



B
$\bar{B}$
7432
$\bar{B} + (A \cdot C) = Fx$
C
A
$(A \cdot C)$

7. See Instructor

8. Yes

PROGRAM: ELECTRONICS

TASK: NAND LOGIC

TASK #: E 4.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ___________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

PERFORMANCE OBJECTIVE:

Using NAND logic, construct basic logic circuits from Boolean expressions.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out of 7 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 7 point or 80%, and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

NAND LOGIC

E 4.5

CRITICAL ITEMS	ITEMS TO BE OBSERVED OR CHECKED	RATING YES/NO	
1.	Was the circuit wired according to the schematic?	Y	N
*2.	Does the circuit function properly?	Y	N
*3.	Was necessary data recorded?	Y	N
4.	Was the correct equipment used?	Y	N
5.	Was the equipment used properly?	Y	N
*6.	Were safety precautions followed?	Y	N
*7.	Was equipment returned to proper storage area?	Y	N

TOTAL POINTS POSSIBLE ___

POINTS NEEDED FOR MASTERY ___

SCORE ___

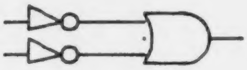
EXAM E 4.6

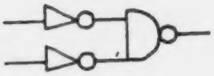
DIRECTIONS:

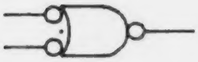
The purpose of this exam is to determine whether or not you have understood the information on using NAND logic, construct basic logic circuits from Boolean expressions. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Shade in the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on the ANSWER SHEET; use a #2 pencil to mark your answers. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM E 4.6 CONT'D.

1. Which of the circuits below is correct for this Boolean expression: A B = Fx?

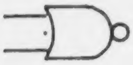
A. 

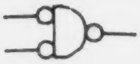
B. 

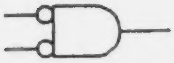
C. 

D. None of these
E. All of these

2. Which of the following is correct for this Boolean expression: A + B = Fx?

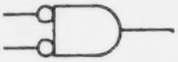
A. 

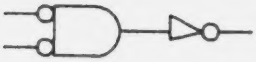
B. 

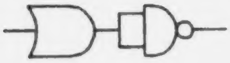
C. 

D. None of these
E. All of these

3. Which of these circuits will perform the NOR function?

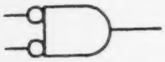
A. 

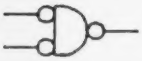
B. 

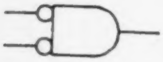
C. 

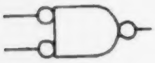
D. None of these
E. All of these

4. Which of these circuits will perform the NAND function?

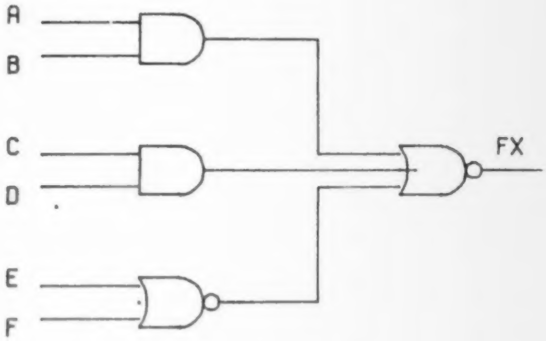
A.


B.


C.


D.


5. Which Boolean expression below is correct for this logic diagram?



A. $\overline{A \cdot B + C \cdot D + E + F} = Fx$

B. $A \cdot B + C \cdot D + E + F = Fx$

C. $A \cdot B + C \cdot D + \overline{E + F} = Fx$

D. $\overline{A \cdot B + C \cdot D + \overline{E + F}} = Fx$

6. The truth table for the circuit of questions number 5 would have _______ switch combinations?

A. 2^8
B. 32
C. 2^6
D. None of these

7. $\overline{\overline{A}} + \overline{\overline{B}}$ is the same thing as:

A. $\overline{\overline{A + B}}$
B. $A \cdot B$
C. $A + B$

D. $\overline{A \cdot B}$

8. Which of the expressions below is a maxterm type of Boolean expression?

A. $A \cdot B + C \cdot D = Fx$

B. $\overline{A \cdot B} + \overline{C} \cdot D = Fx$

C. $\overline{A} \cdot \overline{B} + C \cdot D + \overline{E \cdot D} = Fx$

D. $\overline{A} + \overline{B} \cdot \overline{C + D} = Fx$

9. A four variable K-map has ___ boxes.

A. 4
B. 12
C. 32
D. 16

10. The expression $A \cdot B \cdot C + A \cdot B \cdot C + A \cdot B \cdot C + A \cdot B \cdot C = Fx$ will simplify into:

A. $A \cdot \overline{C} + \overline{A} \cdot \overline{B} = Fx$

B. $A \cdot C + A \cdot B = Fx$

C. $A \cdot \overline{C} + A \cdot \overline{B} = Fx$

D. $\overline{A} \cdot C + \overline{A} \cdot \overline{B} = Fx$

EXAM KEY E 4.6

1. C
2. B
3. E
4. C
5. D
6. C
7. D
8. D
9. D
10. A

ANALYZING DIGITAL ELECTRONIC CIRCUITS

E 5: ENCODING AND DECODING CIRCUITS

TASK: Use logic diagrams to analyze, construct, and troubleshoot encoding and decoding circuits.

PURPOSE: Logic gates can be configured to perform many different functions. They can be used to convert signals into binary codes (encoding). They can be used to break a binary code into a digital output (decode). Sometimes they are configured to select or distribute data (multiplexers and demultiplexers). They might also be used to compare digital signals or check for digital errors (comparitors and parity checkers). On this learning guide you will study these digital circuits and construct and troubleshoot simple logic-using decoders, multiplexers, and parity generators.

OBJECTIVE: Given access to necessary tools and equipment, you will use logic diagrams to analyze, construct, and troubleshoot encoding and decoding circuits. To master this task you must score 80% on a written exam and a performance checklist.

ESTIMATED CLASS TIME: 25 HOURS

ENCODING AND DECODING CIRCUITS

LEARNING STEPS

E 5

READ: Information Sheet E 5.1, "Encoders and Decoders."

READ: Information on encoders and decoders from the following resource list.

COMPLETE: Activity Sheet E 5.2, "Encoders and Decoders."

READ: Information Sheet E 5.3, "Multiplexers and Demultiplexers."

READ: Information on multiplexers and demultiplexers from the following resource list.

COMPLETE: Lab performance on multiplexers and demultiplexers. Contact your instructor.

READ: Information Sheet E 5.4, "Comparators and Parity Generators."

READ: Information on comparators and parity generators from the following resource list.

COMPLETE: Activity Sheet E 5.5, "Parity Generators."

COMPLETE: Lab performance on parity generators. Contact your instructor.

COMPLETE: Performance Checklist E 5.6. Contact your instructor.

COMPLETE: Written Exam E 5.7. Contact your instructor.

ENCODING AND DECODING CIRCUITS

RESOURCES

E 5

1. CMOS DATA MANUAL (Motorola).
2. Brey, DIGITAL ELECTRONICS (Bobbs-Merrill, 1984).
3. Tokheim, DIGITAL ELECTRONICS TEXT AND ACTIVITY MANUAL (McGraw-Hill, 1984).
4. Tocci, DIGITAL SYSTEMS (Prentice-Hall, 1984).
5. DIGITAL TECHNIQUES STUDENT WORKBOOK (Heath Co., 1981).
6. Williams, DIGITAL TECHNOLOGY (SRA, 1982). 2nd Ed.
7. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Ed.
8. Texas Instrument TTL DATA MANUAL.

INFORMATION SHEET

E 5.1

ENCODERS AND DECODERS

Encoding could be defined as "a process of converting an input digital signal into an equivalent binary code." In digital electronics there are several numbering systems used and many different codes which are used. Some of the more common codes are:

1. Binary-coded decimal (BCD) code. This code represents decimal digits 0-9 in four bit combinations.

2. Gray code, a code used to digitalize shaft rotation. This code is unique in that only one bit in the group changes at a time.

3. American Standard Code for Information Interchange (ASCII) is a code used on many keyboards.

4. Extended Binary-Coded-Decimal Interchange Code (EBCDIC), is another code used on keyboards and video displays. Used by IBM.

5. Bardot code, a five bit code used on older model teletype machines.

6. 7-segment display code is a code used to light seven-segment LED displays.

7. Excess-3 code, which is another form of BCD code. This code starts with 0 equal to 0011_2. Figure E 5.1-1 illustrates some of these codes, and should be studied so you become familiar with each.

INFORMATION SHEET E 5.1 CONT'D.

DECIMAL SYSTEM	BINARY	OCTAL	HEXA-DECIMAL
0	0000	0	0
1	0001	1	1
2	0010	2	2
3	0011	3	3
4	0100	4	4
5	0101	5	5
6	0110	6	6
7	0111	7	7
8	1000	10	8
9	1001	11	9
10	1010	12	A
11	1011	13	B
12	1100	14	C
13	1101	15	D
14	1110	16	E
15	1111	17	F

8421 BCD	
	0000
	0001
	0010
	0011
	0100
	0101
	0110
	0111
	1000
	1001
0001	0000
0001	0001
0001	0010
0001	0011
0001	0100
0001	0101

EXCESS −3	
0011	0011
0011	0100
0011	0101
0011	0110
0011	0111
0011	1000
0011	1001
0011	1010
0011	1011
0011	1100
0100	0011
0100	0100
0100	0101
0100	0110
0100	0111
0100	1000

REFLECTED GRAY CODE
0000
0001
0011
0010
0110
0111
0101
0100
1100
1101
1111
1110
1010
1011
1001
1000

7-SEGMENT DISPLAY (1 = ON)							
A	B	C	D	E	F	G	DISPLAY
1	1	1	1	1	1	0	0
0	1	1	0	0	0	0	1
1	1	0	1	1	0	1	2
1	1	1	1	0	0	1	3
0	1	1	0	0	1	1	4
1	0	1	1	0	1	1	5
0	0	1	1	1	1	1	6
1	1	1	0	0	0	0	7
1	1	1	1	1	1	1	8
1	1	1	0	0	1	1	9
1	1	1	1	1	0	1	A
0	0	1	1	1	1	1	B
0	0	0	1	1	0	1	C
0	1	1	1	1	0	1	D
1	1	0	1	1	1	1	E
1	0	0	0	1	1	1	F

Figure E 5.1-1

Encoders can be built from discrete (individual) gates, but as encoding complexity increases so does the gating arrangement. Therefore, encoders are pre-packaged and selected for a particular encoding job. Figure E 5.1-2A, E 5.1-2B, and E 5.1-2C are examples of some commercial encoders.

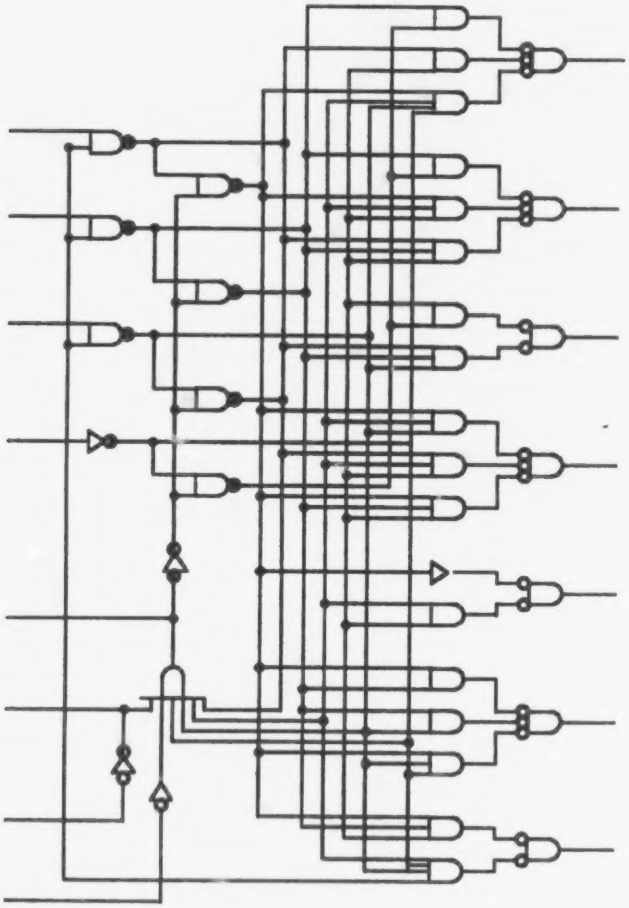


Figure E 5.1-2A
10 to 4 line encoder
(Decimal to BCD)

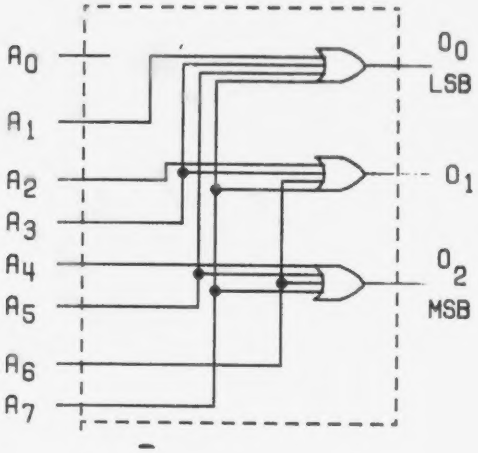

A0
A1
A2
A3
A4
A5
A6
A7
O0
LSB
O1
O2
MSB

Figure E 5.1-2B
8-3 Encoder
(Binary to Octal)

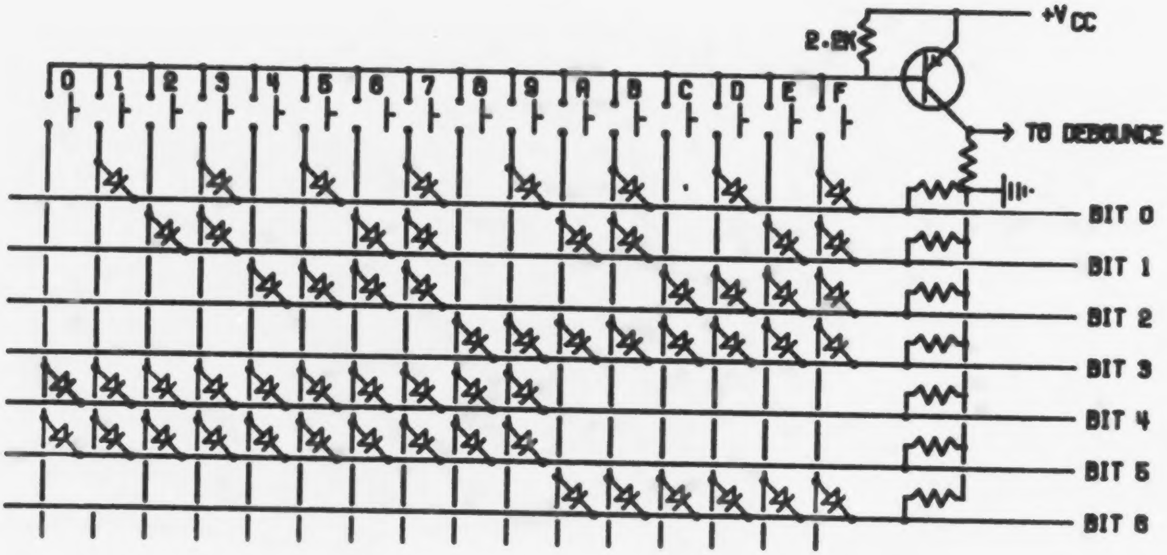

+VCC
2.2K
0
1
2
3
4
5
6
7
8
9
A
B
C
D
E
F
TO DEBOUNCE
BIT 0
BIT 1
BIT 2
BIT 3
BIT 4
BIT 5
BIT 6

Figure E 5.1-2C

Hex keyboard encoded using diode matrix

Decoding is the reverse of encoding i.e., it converts the coded information into a more usable form. An example of a decoding circuit is a 7-segment decoder. This circuit decodes the BCD code into a more usable form to drive the segments of a 7-segment display. Figure E 5.1-3 illustrates a common anode decoder/driver device.

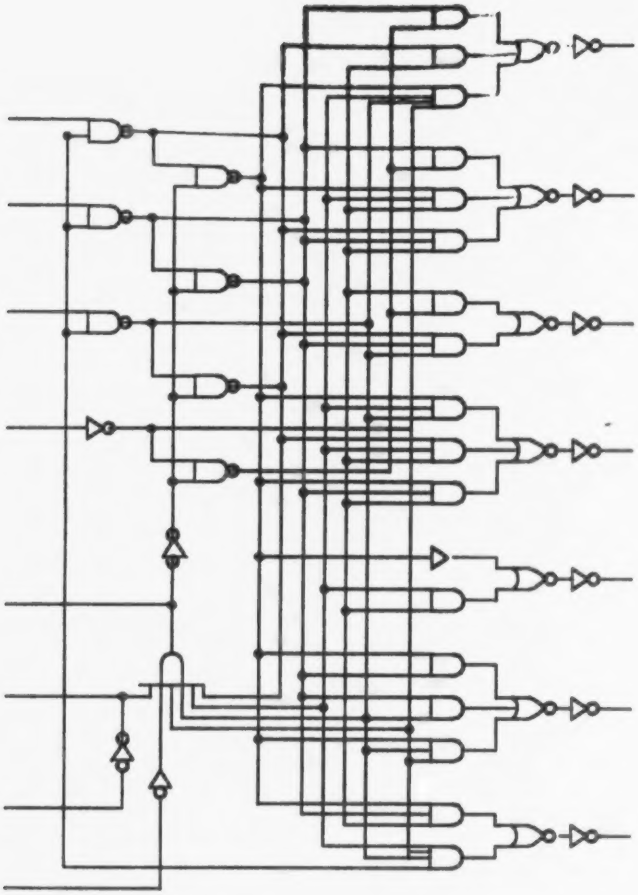


Figure E 5.1-3

The 7-segment decoders are divided into groups according to what they will "drive," LCD, LED, or nixie tubes. The LED types are further divided into common anode (CA) or common cathode (CC). These terms refer to how the LED is constructed. A common anode LED has all of the segment anodes tied together as in Figure E 5.1-4. The common cathode is just the opposite. Each cathode is separate, and is labeled as a segment. They are listed as a-g (plus the decimal point). The 7447 is a 7-segment decoder and driver; not only will it decode each segment for a particular BCD code, but it has the current capacity to light or "drive" the group of segments. The 7448 is a common cathode decoder/driver, and could not be used with a CA display.

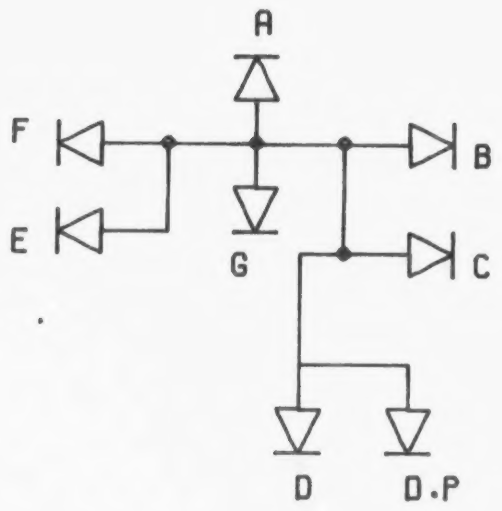


Figure E 5.1-4

There are many different types of encoders and decoders available. It would be to your advantage to check several data books, both CMOS and TTL, to see what is available and what their specifications are.

ACTIVITY SHEET

E 5.2

ENCODERS AND DECODERS

OBJECTIVE:	After completing this activity sheet you should be able to draw and construct simple encoding and decoding circuits.
MATERIALS AND EQUIPMENT:	Logic trainer TTL and CMOS Digital ICS Keypad, 7-seg. display, resistors, LEDS
PROCEDURE:	List all responses in the area of this activity sheet called, "charts, graphs, tables and diagrams."

1. List six codes.
2. Draw a common anode and common cathode display.
3. What 74xx IC is used for driving and decoding a CA display? A CC display?
4. Construct and test this encoder/decoder circuit.

   See Figure E 5.2-1.

ACTIVITY SHEET E 5.2 CONT'D.

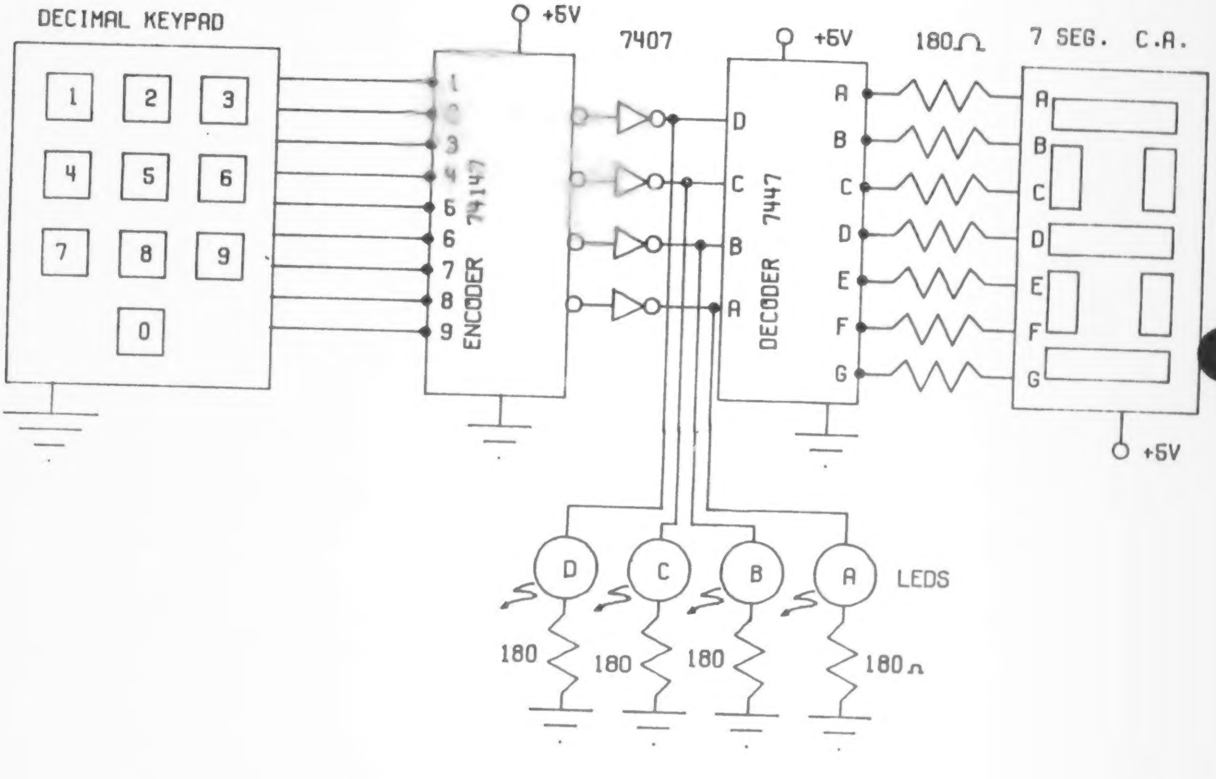

DECIMAL KEYPAD
1
2
3
4
5
6
7
8
9
0
+5V
ENCODER
74147
1
2
3
4
5
6
7
8
9
7407
+5V
DECODER
7447
D
C
B
A
A
B
C
D
E
F
G
180Ω
7 SEG. C.A.
A
B
C
D
E
F
G
+5V
D
C
B
A
LEDS
180
180
180
180Ω

Figure E 5.2-1

ACTIVITY SHEET E 5.2 CONT'D.

5. Answer these questions: (refer to diagram of question 4)

   A. What is the purpose of the 74147?

   B. What are the 7404's used for? Why?

   C. What code is output from the 74174?

   D. What is the function of the 7447?

   E. What purpose do the 180 ohm resistors service?

   F. If you "hit" two keys at the same time what will happen? Why?

6. Define encoder.

7. Define decoder.

8. Draw an 8-to-3 encoder.

9. Check with your instructor to see if there are any further encoder or decoder circuits to construct.

ACTIVITY E 5.2

ANSWER SHEET

1. Codes:

   A.

   B.

   C.

   D.

   E.

   F.

2. Common anode　　　　　　Common cathode

3. CA 74

   ____

4. CC 74

   ____

5. A. 74147 ____

   ____

   B. ____

   ____

   C. ____

   ____

   D. ____

   ____

   E. ____

   ____

   F. ____

   ____

ACTIVITY SHEET E 5.2 CONT'D.

6. ______________________________

7. ______________________________

8. 8-to-3 encoder--

INFORMATION SHEET

E 5.3

MULTIPLEXERS AND DEMULTIPLEXERS

Multiplexers (abbreviated MUXS) is a digital circuit used to receive logic, data, on multiple input lines and output the data on a single output line. Multiplexers are some times referred to as data selectors. A multiplexer can be thought of as an "electronic rotary switch." A general description of multiplexing is, "any mixing of signals from multiple sources into lesser number of outputs." Some microprocessors use multiplexing to place 16 signals on 8 lines. There are many multiplexing schemes which may be used. Figure E 5.3-1 is an example of an 8-to-1 line multiplexer. D_7 through D_0 are the inputs and T is the output. Each input can be sequenced or selected by placing the proper binary code on the select lines, A_0-A_2. The inhibit input is used as a "master lock" to turn-on or turn-off the entire circuit. Multiplexers can be built from discrete gates; however, they are usually pre-packaged devices.

In contrast to multiplexers, a demultiplexer (DMUX) takes data from one source and distributes it according to same pattern on several output lines. Demultiplexers are sometimes referred to as data distributors. A common analogy for a DMUX unit is a car's distributor. Figure E 5.3-2 is an example of an eight-channel demultiplexer. Serial data is input on the input line and each output is selected by sequentially applying a binary code on inputs A_0-A_2. The data from the input is distributed according to which output has been "selected" by the input A_0-A_2. Demultiplexers can also be used as decoders. If the input is "tied" to a log low continuously, the outputs will represent the binary count defined by the logic on A_0, A_1, and A_2. Figure E 5.3-2 could be used as a 3-to-8 decoder.

Demultiplexers reverse the operation of the multiplexer, that is they take on input and provide multiple outputs. By using a multiplexer and a demultiplexer together as in Figure E 5.3-3, data could be transferred via one line instead of sixteen.

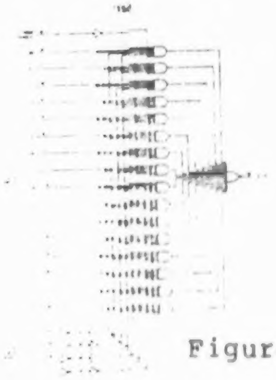


Figure E 5.3-1

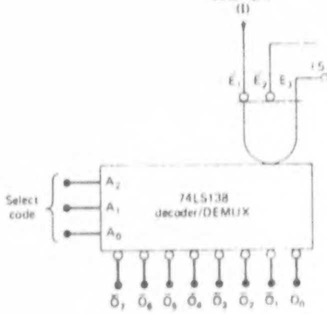


Figure E 5.3-2

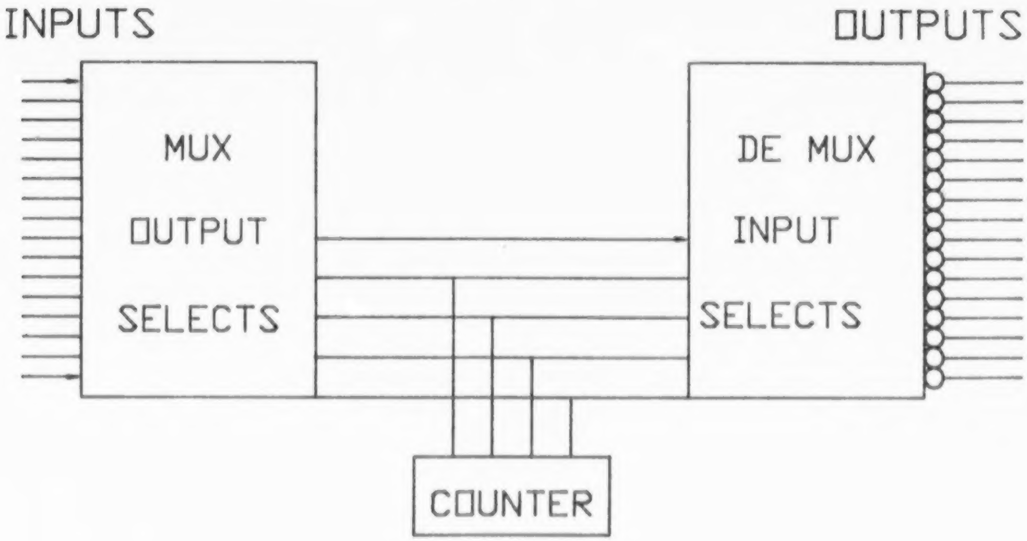


Figure E 5.3-3

Many time multiplexers are used with displays to reduce the number of encoders which would be required. As a general rule, if a display requires four or more digits, it would be best to multiplex it rather than use discrete decoders and drivers. Figure E 5.3-4 is a block diagram representation of a multiplexed display. The heart of the circuit is controlled by an astable clock which is used to clock the counter at a rate such that the switching will be undetected by the human eye. The counter is a modulo-8 counter which will be used to select one of the eight digits. There are two data selectors or multiplexers on this circuit. One could be classified as a 3-to-8 line unit which is used to scan, or turn on the digits. The second unit has multiple inputs used for the BCD data. There will be BCD data equal to the number of digits, in this case 8. The important thing to notice about this circuit is its use of only one decoder driver. The operation of the multiplexed display is quite simple. When the count from the counter is 000 the zero line on the scan decoder and the input multiplexer are activated. The zero or first digit will be active and the BCD information present on the first set of inputs will be made available to the decoder driver. When the counter counts up to one, the next digit and BCD data will be activated and the procedure will continue to cycle.

The effect will be an optical illusion that all of the digits are on at the same time, when in reality only one is ever on at a time.

There are many types of multiplexers and demultiplexers and many applications and circuit configurations. It would be to your benefit to review some of the different multiplexers in the data books in your laboratory.

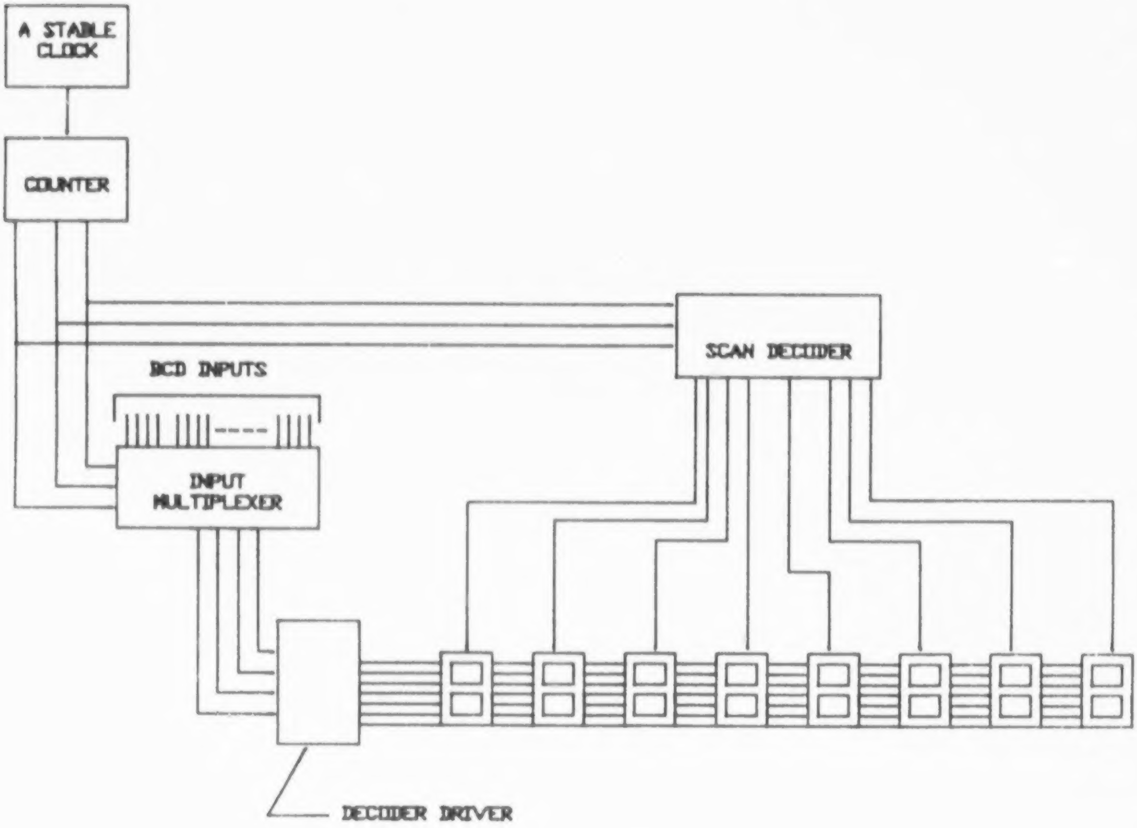

A STABLE CLOCK
COUNTER
SCAN DECODER
BCD INPUTS
INPUT MULTIPLEXER
DECODER DRIVER

Figure E 5.3-4

Multiplexing a Seven Segment Display

INFORMATION SHEET

E 5.4

COMPARATORS AND PARITY GENERATORS

Digital comparators are used to compare binary numbers. They can tell whether one number is equal to another, or if it is larger than another. Comparators are used in digital arithmetic and control circuits, where two pieces of data need to be compared. Figure E 5.4-1 is an example of one section of a quad XNOR comparator.

By examining the truth table, you can see the function of the comparator. If both inputs are equal the output is high. If one output is greater than the other the output is low. This is a relatively simple comparator. Figure E 5.4-2 is a more elaborate comparator which will compare 5 bits of data and determine whether one group of 5 is equal to, greater than, or less than another group of 5 bits. E is an enable input used to turn ON or OFF the entire circuit. The bar above the E indicates this input is low active. This means it takes a logic 0 on that input to have the circuit operating. The truth table for the circuit is shown below:

A	B	F_x
0	0	1
1	0	0
0	1	0
1	1	1

TRUTH TABLE

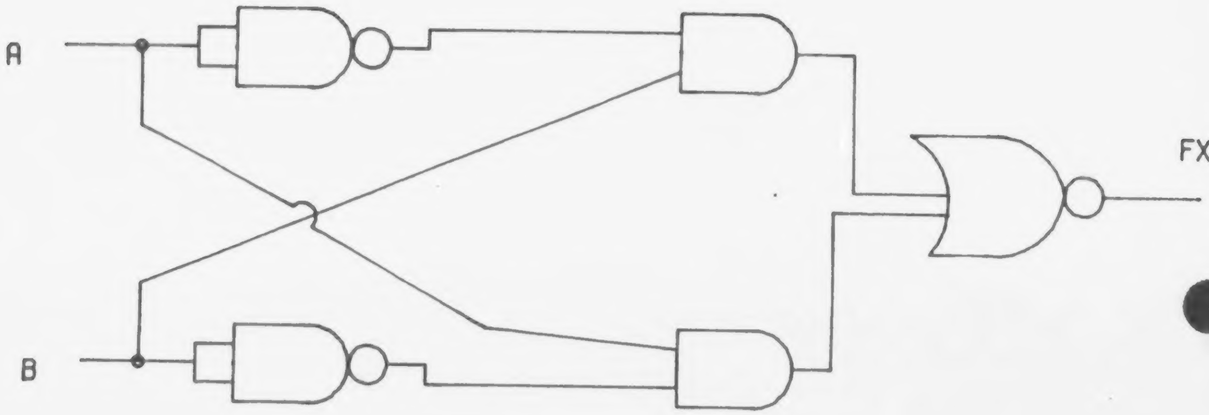


Figure E5.4-1

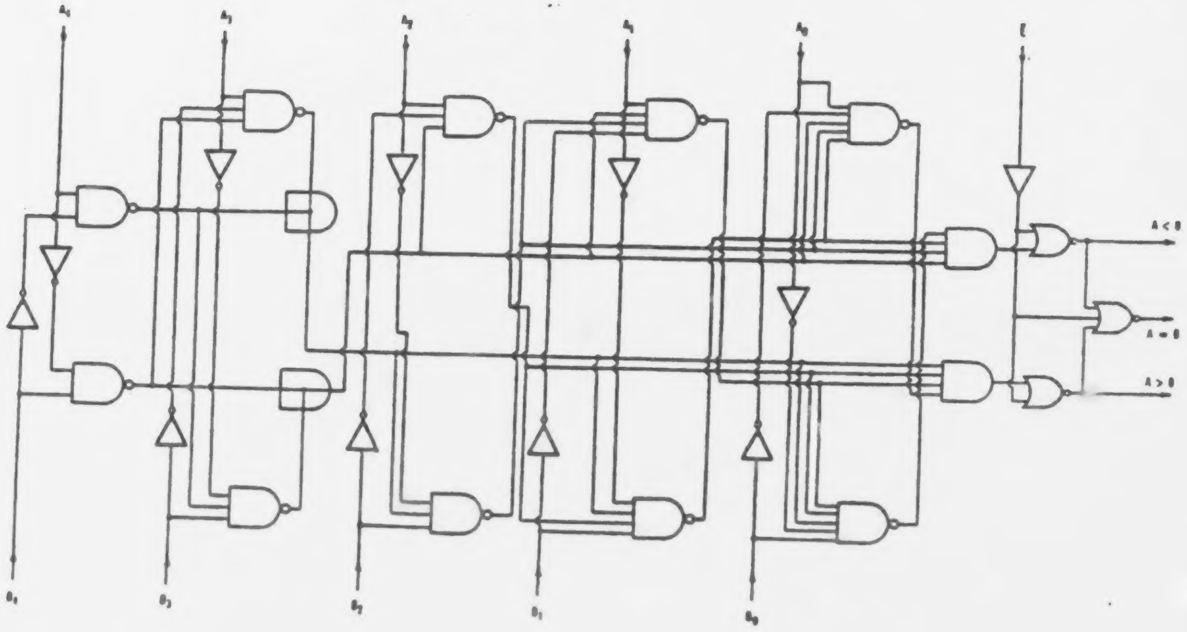


Figure E5.4-2

Comparators and Parity Generators

1140

While transferring data, errors can occur. What is needed is a method of checking for errors. Data is usually transferred in groups of 8 bits, which are referred to as a byte. The most common way to detect an error is to count the number of logic 1 bits in a 7-bit character. If the number of these bits is odd (1, 3, 5, 7) one more 1 bit is added to the group and the 8-bit group now has an even number of logic 1 bits. By contrast if the 7-bit character had an even number of 1's (0, 2, 4, 6) no 1 bit would be added; instead a logic 0 would be inserted in the group. The net effect of all of this is to have an even number of 1's in the 8-bit groups before they are transferred.

At the receiving end of the circuit or system the 1 bits would be counted. If an odd number of 1's were counted, an error would be indicated. This process is called "parity checking," and this particular type of parity is called, "even parity." If an odd number of 1's were counted and sent, the parity system would be called, "odd parity." Both systems are used in digital logic circuits.

Figure E 5.4-3 is an 8-bit parity/generator/checker. To generate a parity bit for transmission with an 8-bit data word, the 8-bit word is loaded on inputs D_0-D_7. If even parity is desired a logic 0 is loaded on D_8. At the receiving end the 9 bits (8 data and 1 parity) are input into an identical parity checker/generator. Since the parity is known at the beginning of transmission, any change in data will be detected by the receiver.

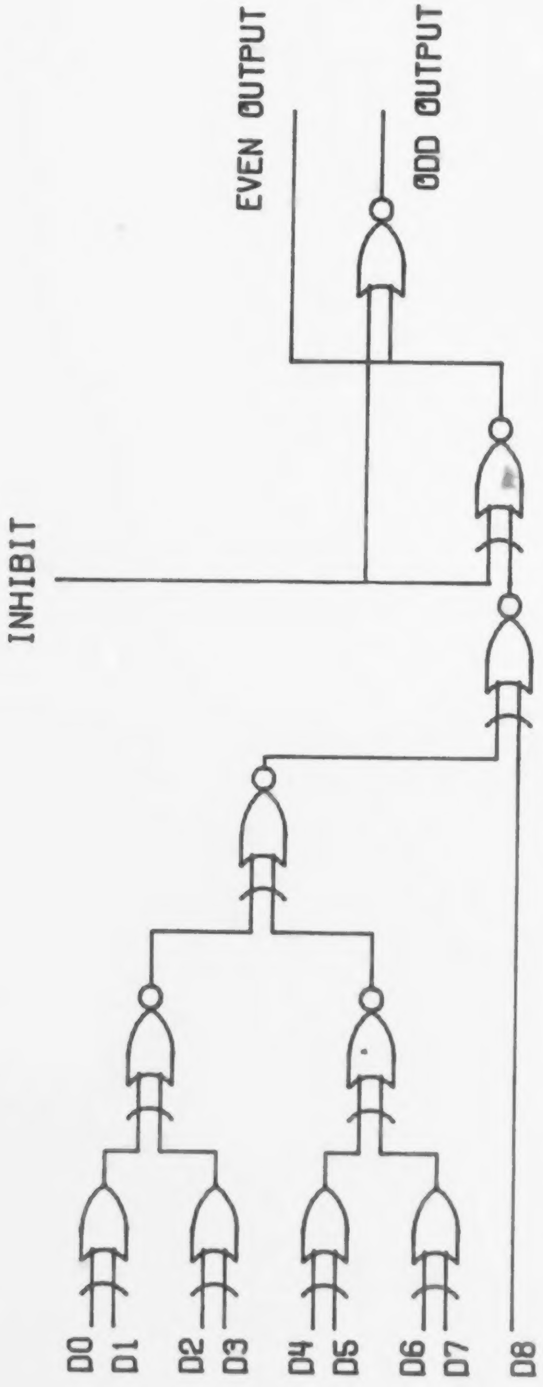

EVEN OUTPUT
ODD OUTPUT
INHIBIT
D0
D1
D2
D3
D4
D5
D6
D7
D8

Figure E 5.4-3

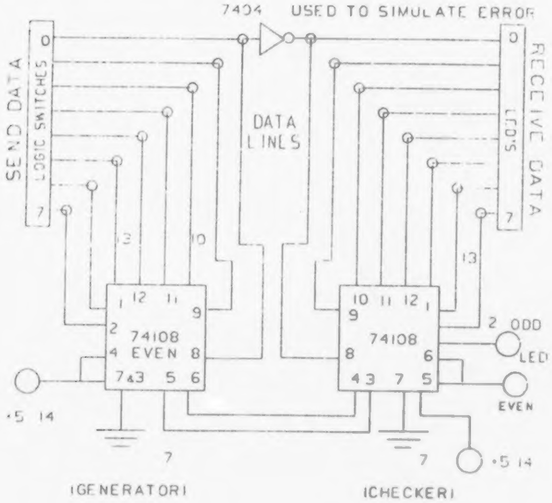
ACTIVITY SHEET

E 5.5

PARITY GENERATORS

OBJECTIVE: Provide a practical example of the operation of a parity generator/checker.

EQUIPMENT AND MATERIALS:
Logic trainer
2 8-bit parity gen. (74180)
1 7404 Hex inverter
LED'S


7404
USED TO SIMULATE ERROR
SEND DATA
LOGIC SWITCHES
0
7
DATA LINES
RECEIVE DATA
LED'S
0
7
13
10
13
1
12
11
9
2
74108
4
EVEN
8
7&3
5
6
10
11
12
1
9
2
ODD
74108
8
6
LED
4 3
7
5
EVEN
•5 14
7
7
•5 14
(GENERATOR)
(CHECKER)

PROCEDURE:

1. Breadboard the circuit above on your logic trainer.
2. This circuit will be used to simulate an 8-bit data line. The logic switches will be used to load data, and the LEDS will be used to monitor the data. (Note the single inverter is used to simulate an error.)
3. Load data by using the logic switches. Load 1, 0, 1, 0, 1, 0, 1, 0.
4. Do you have an even or odd parity light? Why? (Remember all responses go on the page marked "chart, graphs, and diagrams."

ACTIVITY SHEET E 5.5 CONT'D.

5. Load more data. Use any combination of one's and zero's you want.

6. Did the same light go on?____________ If so, why?

7. Turn off the power and remove the 7404 inverter from data line "0."

8. Apply power. Which parity light is on, even or odd. Why?

9. Draw a schematic diagram for odd output parity.

10. Breadboard the circuit and repeat steps 3 through 8. (Remember to put 7404 inverter back in place).

11. Write a short paragraph detailing how this circuit operates.

ACTIVITY SHEET

E 5.5

CHARTS, GRAPHS, TABLES, & DIAGRAMS

4. Even/Odd (Circle one) Why?

6. Yes/No (Circle one) Why?

8. Even/Odd (Circle one) Why?

9.

11. (Paragraph):

PROGRAM: ELECTRONICS

TASK: ENCODING AND DECODING CIRCUITS

TASK #: E 5.6

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

PERFORMANCE OBJECTIVE:

Use logic diagrams to analyse, construct, and troubleshoot encoding and decoding circuits.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out of 8 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 8 points or 80% and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

ENCODING AND DECODING CIRCUITS

E 5.6

CRITICAL ITEMS	ITEMS TO BE OBSERVED OR CHECKED	RATING YES/NO	
1.	Was the circuit wired according to the schematic?	Y	N
*2.	Does the circuit function properly?	Y	N
*3.	Was necessary data recorded?	Y	N
4.	Was the correct equipment used?	Y	N
5.	Was the equipment used properly?	Y	N
*6.	Were safety precautions followed?	Y	N
*7.	Was equipment returned to proper storage area?	Y	N

TOTAL POINTS POSSIBLE ___

POINTS NEEDED FOR MASTERY ___

SCORE ___

EXAM E 5.7

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on encoders and decoders. Each of the questions or incomplete statements is true or false. Place the letter associated with that choice (A or B) in the numbered blank space on your ANSWER SHEET. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer 10 out of 12 items correctly, 80%.

1. Converting a digital input signal to an equivalent binary code is decoding.

   A. True
   B. False

2. BCD stands for binary-coder-decoder.

   A. True
   B. False

3. Only one bit changes at a time in the gray code.

   A. True
   B. False

4. The excess 3 code is used for LEDs.

   A. True
   B. False

5. A 7448 is a 7 segment decoder/driver.

   A. True
   B. False

6. A MUX is a device which takes multiple inputs and puts them on a single output.

   A. True
   B. False

7. The select lines on a multiplexer serve as master lock lines to turn device ON or OFF.

   A. True
   B. False

8. Demultiplexers are sometimes referred to as data distributors.

   A. True
   B. False

9. Parity generators are used to check if one binary number is larger than another.

   A. True
   B. False

10. A "bar" above an input indicates the input is low active.

    A. True
    B. False

11. If an odd number of 1's are sent, the parity generator has odd parity.

    A. True
    B. False

12. Two errors on an 8-bit line could go undetected.

    A. True
    B. False

EXAM KEY E 5.7

1. B (encoding)

2. B (binary coded decimal)

3. A

4. B (usually arithmetic circuits)

5. A

6. A

7. B (inhibit line serves this purpose)

8. A

9. B (comparators)

10. A

11. A

12. A

ELECTRONICS

ANALYZING DIGITAL ELECTRONIC CIRCUITS

E 6: FLIP-FLOPS

TASK: Use logic diagrams to analyze, construct, and trouble-shoot flip-flops.

PURPOSE: The purpose of this learning guide is to introduce you to what is often referred to as sequential logic. Up to this point you have only worked with gates and other "combinational" logic circuits. Flip-flops are basic memory devices which require a clock signal to sequence their operation. After you complete this learning guide, you should be able to wire up basic flip-flops and generate truth tables to gain an understanding of how they operate.

OBJECTIVE: Given access to all necessary tools and equipment, you will use logic diagrams to analyze, construct, and troubleshoot flip-flops. To master this task, you must score 80% on a written exam and performance checklist.

ESTIMATED CLASS TIME: 10 HOURS

FLIP-FLOPS

LEARNING STEPS

E 6

READ: Information Sheet E 6.1, "Flip-flops."

READ: Information on flip-flops in one or more resources listed below.

COMPLETE: Activity sheet E 6.2 on "Flip-flops."

COMPLETE: Lab performance on flip-flops. Contact your instructor.

REVIEW: Review all material covered in this learning guide.

COMPLETE: Performance Checklist E 6.3. Contact your instructor.

COMPLETE: Written Exam E 6.4. Contact your instructor.

FLIP-FLOPS

RESOURCES

E 6

1. CMOS DATA MANUAL, (Motorola).
2. Brey, DIGITAL ELECTRONICS, (Bobbs-Merrill, 1984).
3. Tokheim, DIGITAL ELECTRONICS TEXT AND ACTIVITY MANUAL, (McGraw-Hill, 1984).
4. Tocci, DIGITAL SYSTEMS, (Prentice-Hall, 1984).
5. DIGITAL TECHNIQUES STUDENT WORKBOOK, (Heath Co., 1981).
6. Williams, DIGITAL TECHNOLOGY, (SRA, 1982. 2nd Ed.).
7. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS, (McGraw-Hill, 1983). 2nd Ed.
8. Texas Instrument, TTL DATA MANUAL.

INFORMATION SHEET

E 6.1

FLIP-FLOPS

TERMS AND DEFINITIONS:

1.	Flip-Flop:	A fundamental digital memory unit which is capable of storing one bit of information.
2.	Clock pulse:	Pulse used to gate information into a digital flip-flop circuit.
3.	Set:	To place a storage circuit into one of two states.
4.	Reset:	To return a storage circuit to an initial state.
5.	Positive edge triggered:	A device which changes output logic on the leading edge of a clock pulse.
6.	Negative edge triggered:	A device which changes output logic on the falling edge of a clock pulse.
7.	Level triggered:	A device which changes output logic on the level portion of the clock pulse.
8.	Asynchronous:	Not controlled by clock pulses.
9.	Synchronous:	Controlled by equal-spaced clock pulses.
10.	Clear:	An asynchronous input that will set the output Q of a flip-flop to a logic 0.
11.	Preset:	An asynchronous input which will set the output Q to a logic 1.
12.	Combinational logic:	A simple switching circuit which contains no memory. The output depends only on the present inputs.
13.	Sequential logic:	A logic circuit that uses present data to create further data. Sequential logic circuits exhibit memory.

14. D-Type flip-flop: A special flip-flop which transfers the data present on the D input to the output when a clock pulse is received.

15. Latch-flip-flop: A device that can store a logic 1 or logic 0 by latching the input information onto an output.

16. Master-slave flip-flop: A flip-flop constructed from two gated latches. The master accepts input data on the "1" level portion of the clock pulse, and the slave accepts data from the master on the "0" level of the clock.

17. Trigger: An input to a digital device that starts an event.

18. Timing diagram: A diagram which shows the voltage level and timing between inputs and outputs.

A flip-flop unlike a simple gate has memory. Its output depends not only on present inputs, but also on previous inputs. Figure E 6.1-1 is an example of a simple RS flip-flop made from NAND gates.

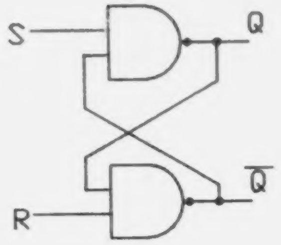


Figure E 6.1-1

Figure E 6.1-2 is a truth table for a RS flip-flop.

INPUTS		OUTPUTS		
S	R	Q	$\overline{Q}$	EFFECTS ON Q
0	0	1	1	PROHIBIT
0	1	1	0	SET Q HIGH
1	0	0	1	RESET Q LOW
1	1	Q	Q	MEMORY

Figure E 6.1-2

Several important items to note are:

1. There are two outputs, one marked Q and the other the complement (opposite) of Q. The bar indicates a complement. This means that if Q is low then $\overline{Q}$ must be high and vice versa.

2. The inputs are marked S (set) and R (reset). They are identified by the effect they have on the Q output.

3. Another interesting point is the connection of the outputs back to inputs; this is called "feedback."

4. The final item is covered by the truth table. It has four possible inputs and four effects on the outputs. The middle two sets of inputs set, and reset Q. The first set of conditions, both inputs low, creates an illogical output, and will be corrected in other flip-flops. The last set of inputs causes no change; this is memory. It is this characteristic which makes the flip-flop useful. Figure E 6.1-3 represents the logic symbol for an RS flip or latch.

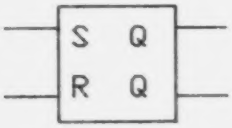
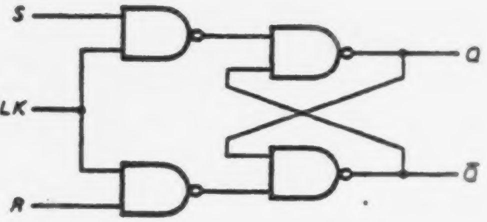


Figure E 6.1-3

The basic RS flip-flop can be modified by adding two NAND gates and an input for a clock. This makes the flop a synchronous device; that is, it is now controlled by a clock. Below are the truth table and logic diagram for a clocked RS flip-flop. Also, there is a diagram which relates the flip-flop's inputs and outputs to time. This diagram is called a timing diagram. The point to note is that the clock now controls the transfer of data from inputs to output. If you study the timing diagram, you will see that the Q output will not change, or follow S until a clock pulse is present.

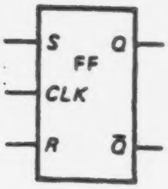
Clocked RS Flip-Flop



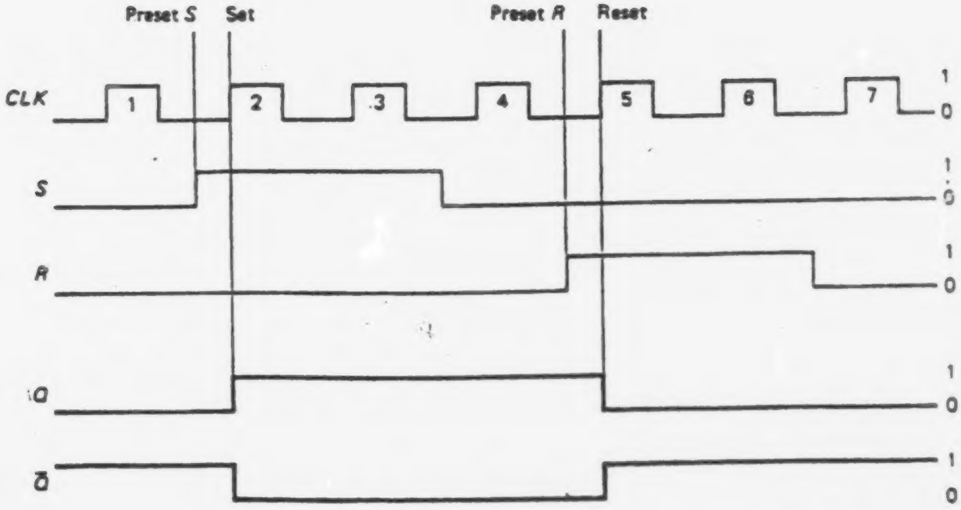
Truth Table:

INPUTS			OUTPUTS		
CLK	S	R	Q	Q̄	Effect on output Q
⎍	0	0	No change		No change
⎍	0	1	0	1	Reset or cleared to 0
⎍	1	0	1	0	Set to 1
⎍	1	1	1	1	Prohibited—do not use

Logic Symbol:

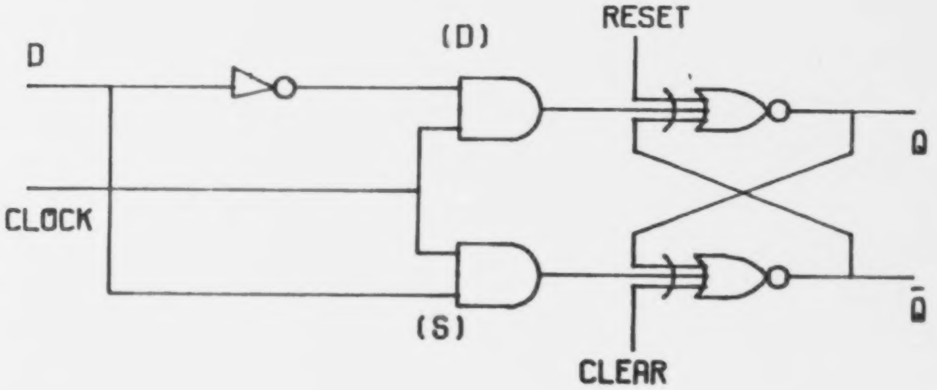


Timing Diagram:


Preset S
Set
Preset R
Reset
CLK
S
R
Q
Q̄
1
2
3
4
5
6
7
1
0

The basic RS flip-flop can be modified further by adding an inverter to the reset input. When the flip-flop is configured in this way, it is called a "D" flip-flop. The advantage of this configuration is to remove the prohibit state, both inputs high, characteristic of the basic RS. The operation of the D flip-flop is best explained by looking at its timing diagram. The output Q will follow D when the clock makes a positive-going transition. This is an example of positive-edge triggering. Two new inputs have been added to this flip-flop, preset and clear. The logic symbol shows these as being low active. Anytime a "bubble" is drawn on a flip-flops input, it means a logic 0 is required to activate the input. These two new inputs are called "overriding inputs." They will clear Q to 0 or set Q to 1 no matter what inputs are on D or the clock. Study these diagrams to become familiar with the D flip-flop.

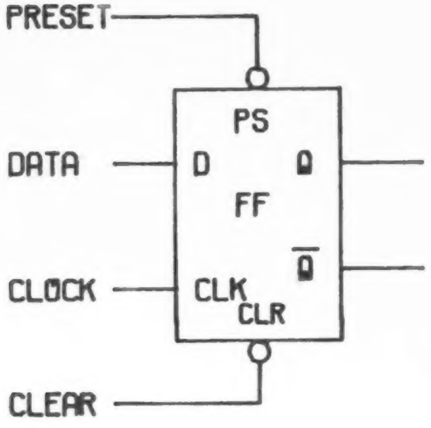
Logic Diagram:



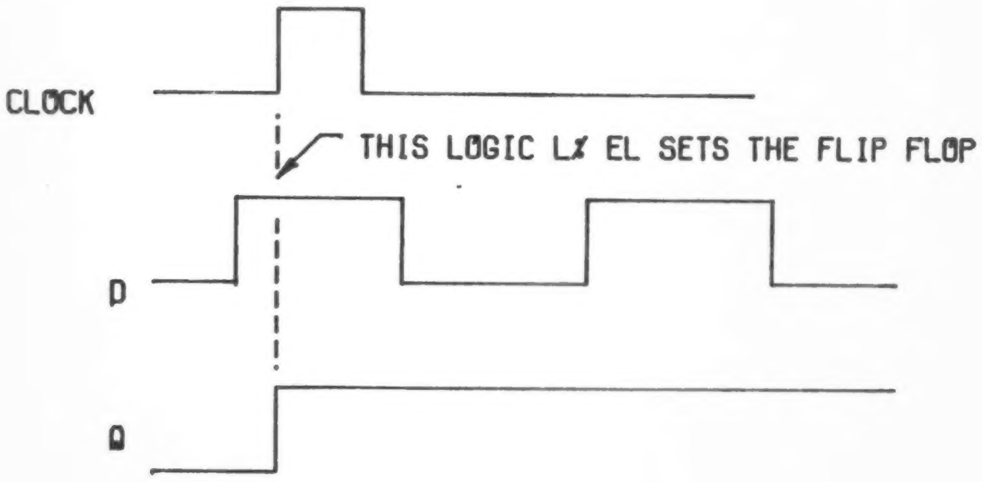
Truth Table:

Input	Output
D	Q^{n+1}
0	0
1	1

Logic Symbol:


PRESET
PS
DATA
D
Q
FF
$\overline{Q}$
CLOCK
CLK
CLR
CLEAR

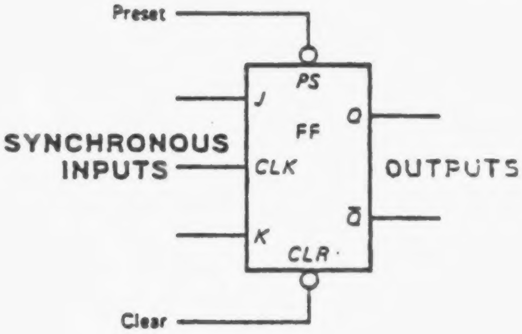
Timing Diagram:


CLOCK
THIS LOGIC LEVEL SETS THE FLIP FLOP
D
Q

The J-K flip-flop is still another version of the basic RS flip-flop. The J-K flip-flop is probably the most widely used of all the flip-flops. The logic symbol is drawn below. It has two inputs, J and K. The truth table shows that Q "follows" J and Q "follows" K. Notice that the prohibit state, both inputs high, has been eliminated. This position is now referred to as the "toggle" position. When both inputs on a J-K are tied high, the output will toggle every other clock pulse. This makes the J-K useful for frequency division. If you study the timing diagram, you will see this J-K uses master-slave triggering. At point "A" on the timing diagram, the input is presented to the master flip-flop. At point "B" the inverter "locks" out the slave flip-flop. During the one or level portion of the clock pulse the slave is reset and, via the feedback lines, allows master to set. On the falling edge of the clock the inverter clocks the data present on the master's output onto the slave; thus you have master-slave triggering.

This information sheet has illustrated some of the basic concepts involved with flip-flops. These devices are digital "building blocks" for counter and shift registers. It would be to your advantage to have a good understanding of their behavior.

Logic Symbol:

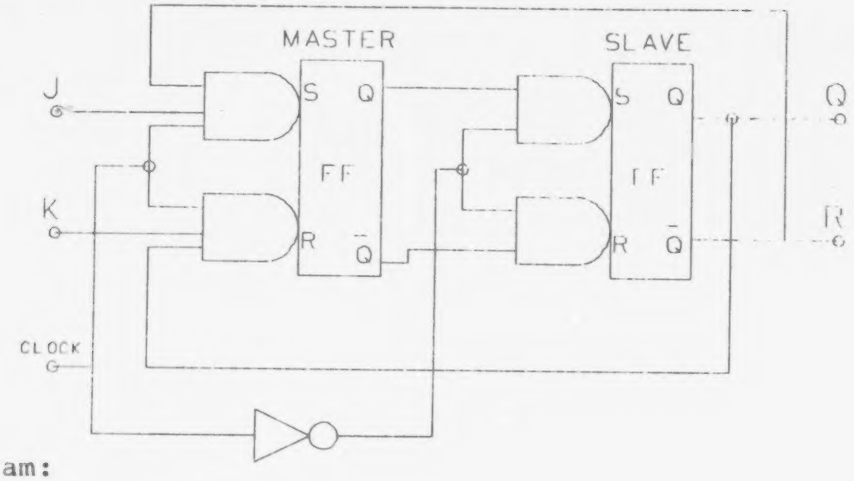


Truth Table:

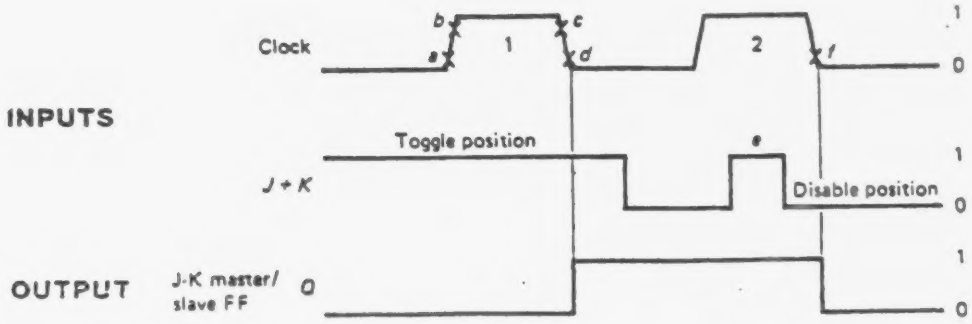
INPUTS			OUTPUTS		
CLK	J	K	Q	$\bar{Q}$	Effect on output Q
⎍	0	0	No change		No change – disable
⎍	0	1	0	1	Reset or cleared to 0
⎍	1	0	1	0	Set to 1
⎍	1	1	Toggle		Changes to opposite state

INFORMATION SHEET E 6.1 CONT'D.

Functional Block Diagram:


MASTER
SLAVE
J
K
CLOCK
S
Q
FF
R
Q̄
S
Q
FF
R
Q̄
Q
R

Timing Diagram:



ACTIVITY SHEET

E 6.2

FLIP-FLOPS

1. Draw the following for an RS flip-flop:

   A) Logic Symbol B) Truth Table

   C) Timing Diagram

2. Draw the following for a clocked-RS flip-flop:

   A) Logic Symbol B) Truth Table

   C) Timing Diagram

3. Draw the following for a D flip-flop:

   A) Logic Symbol B) Truth Table

   C) Timing Diagram (Positive-edge triggered)

ACTIVITY SHEET E 6.2 CONT'D.

4. Draw the following for a J-K flip-flop:

   A) Logic Symbol B) Truth Table

   C) Timing Diagram(master-slave triggering with preset and clear)

5. Define these terms:

   A) Synchronous

   B) Asynchronous

   C) Trigger

   D) Sequential

6. Explain the following types of triggering:

   A) Positive

   B) Negative

   C) Master-slave

7. Explain the function of these two inputs:

   A) Preset

   B) Clear

ACTIVITY SHEET E 6.2 CONT'D.

8. Using a TTL data book and a CMOS data book, list flip-flops by number and type.

   A)

   B)

   C)

   D)

   E)

   F)

   G)

   H)

   I)

   J)

ACTIVITY SHEET E 6.2

ANSWERS SHEET

1. Refer to text.

2. Refer to text.

3. Refer to text.

4. Refer to text.

5. Synchronous--clock controlled.

6. Asynchronous--not affected by clock or clock not used.

7. Trigger--start an event.

8. TTL
   7473 D type
   7474 dual D pos.-edge triggered
   74174 Hex D pos.-edge triggered
   7476 dual J-K master-slave
   74107

   4013B dual D flip-flop
   4027B dual J-K
   4076B quad D
   4044B quad NAND latch
   4174 Hex D flip-flop

PROGRAM: ELECTRONICS

TASK: FLIP-FLOPS

TASK #: E 6.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME__________________________ EVALUATION SITE____________

EVALUATOR'S NAME______________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Use logic diagrams to analyze, construct, and trouble-shoot flip-flops.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out of 8 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 8 points or 80% and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

FLIP-FLOPS

E 6.4

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
1.	Was the circuit wired according to the schematic?	Y	N
*2.	Does the circuit function properly?	Y	N
*3.	Was necessary data recorded?	Y	N
4.	Was the correct equipment used?	Y	N
5.	Was the equipment used properly?	Y	N
*6.	Were safety precautions followed?	Y	N
*7.	Was equipment returned to proper storage area?	Y	N

TOTAL POINTS POSSIBLE ___

POINTS NEEDED FOR MASTERY ___

SCORE ___

EXAM E 6.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on flip-flops. Each of the questions or incomplete statements is true or flase. Place the letter associated with that choice (A or B) in the numbered blank space on you ANSWER SHEET. DO NOT WRITE ON THIS TEST!!!! To master this exam you must answer 10 out of 13 items correctly, 80%.

EXAM E 6.4 CONT'D.

1. A J-K flip-flop is usually negative-edge triggered.

   A. True
   B. False

2. Clear and reset are synchronous inputs.

   A. True
   B. False

3. The data is transferred to the output on the negative edge of the clock when master-slave triggering is used.

   A. True
   B. False

4. A timing diagram is much like the output of an oscilloscope.

   A. True
   B. False

5. Two ones on a clocked RS flip-flop are prohibited.

   A. True
   B. False

6. A "race" condition on a flip-flop is desired.

   True
   False

7. Two AND gates are added to the basic RS flip-flop to make it a clocked device.

   A. True
   B. False

8. The "delay" flip-flop uses an inverter on one input.

   A. True
   B. False

9. On a D flip-flop Q follows D.

   A. True
   B. False

EXAM E 6.4 CONT'D.

10. The J-K flip-flop is the most commonly used flip-flop.

    A. True
    B. False

11. A "T" flip is a J-K with both inputs tied low.

    A. True
    B. False

12. The clock can override the clear input.

    A. True
    B. False

13. Q "follows" K input.

    A. True
    B. False

EXAM KEY E 6.4

1. B
2. B
3. A
4. A
5. A
6. B
7. B
8. A
9. A
10. A
11. B
12. B
13. B

ELECTRONICS

ANALYZING DIGITAL ELECTRONIC CIRCUITS

E 7: MULTIVIBRATORS

TASK:	Analyze, construct, and troubleshoot basic multivibrator circuits.
PURPOSE:	Multivibrator circuits are relaxation oscillators used to produce a period wavetrain to operate sequential circuits. These devices could be equated to the human heart, in that they provide the timing pulses required to keep the digital system functioning. This learning guide will cover a few of the many types of oscillator circuits. After you complete this guide you should be able to explain the operation of an astable and a monostable multivibrator. You should also be able to construct and troubleshoot oscillator circuits.
OBJECTIVE:	Given access to all necessary tools and equipment, you will analyze, construct, and troubleshoot basic multivibrator circuits. To master this task you must score 80% on a written exam and performance checklist.

ESTIMATED CLASS TIME: 10 HOURS

MULTIVIBRATORS

LEARNING STEPS

E 7

READ: Information Sheet E 7.1, "Multivibrator Circuits."

READ: Information on multivibrator circuits in one or more resources below.

COMPLETE: Activity Sheet E 7.2 on "Multivibrator Circuits."

COMPLETE: Lab performance on multivibrator circuits. Contact your instructor.

REVIEW: All material covered in this learning guide.

COMPLETE: Performance Checklist E 7.3. Contact your instructor.

COMPLETE: Written Exam E 7.4. Contact your instructor.

MULTIVIBRATORS

RESOURCES

E 7

1. CMOS DATA MANUAL (Motorola).
2. Brey, DIGITAL ELECTRONICS (Bobbs-Merrill, 1984).
3. Tokheim, DIGITAL ELECTRONICS TEXT AND ACTIVITY MANUAL (McGraw-Hill, 1984).
4. Tocci, DIGITAL SYSTEMS (Prentice-Hall, 1984).
5. DIGITAL TECHNIQUES STUDENT WORKBOOK (Heath Co., 1981).
6. Williams, DIGITAL TECHNOLOGY (SRA, 1982). 2nd Ed.
7. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Ed.
8. Texas Instrument TTL DATA MANUAL.

INFORMATION SHEET

E 7.1

MULTIVIBRATOR CIRCUITS

Listed below are terms used with oscillator and multivibrator circuits. Comprehension of these terms will aid your understanding of multivibrator circuits.

Oscillator:	An electronics circuit that converts DC to AC. Classified as either sinusoidal or nonsinusoidal.
Relaxation Oscillator:	An oscillator whose output is nonsinusoidal.
Astable Multivibrator:	A relaxation oscillator with no stable states. The circuit voltages swing constantly as it oscillates.
Monostable Multivibrator:	One stable state. A circuit that generates a a fixed-duration output pulse each time it receives an input pulse.
RC time Constant:	The period of time required to charge a capacitor through a resistance to 63% of the capacitor's full charge. Used in timing circuits.
Crystal Control:	Oscillator using a quartz crystal to produce a reference for oscillation.
Duty cycle:	Relates to the percent of time the pulse is OFF to the total time period, T.
Schmitt Trigger:	A circuit used to convert sine waves and other wave forms into pulses.
Clock Generator:	A circuit used to create a frequency of periodic pulses used for timing in a digital system.

INFORMATION SHEET E 7.1 CONT'D.

A multivibrator circuit can be built from discrete transistors, operational amplifier, digital gates, or special timer integrated circuits. Figure E 7.1-1 is an example of an astable multivibrator built from discrete bipolar transistors. The operation of this circuit is very straight forward. The ON and OFF periods of the circuit are controlled by R_1-C_1 and R_2. The circuit output is a squarewave at a frequency of approximately $\frac{1}{1.4\ (R_1C_1)}$. Hence, the frequency can be decreased by raising the values of the capacitors C_1 and C_2, or the resistors R_1 and R_2.

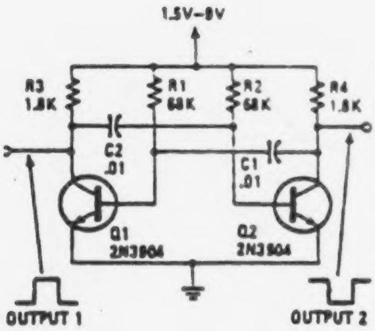


Figure E 7.1-1

Figure E 7.1-2 is an example of an op amp used as a squarewave generator. R_2 and R_3 provide feedback to the non-inverting input and set the upper and lower triggerpoints. R_1 and C_1 form an RC circuit and set the frequency of operation. This circuit will provide a symmetrical output squarewave whose frequency can be roughly calculated by, provided R_1 R_2.

$$F = \frac{1}{2\ R_1\ C_1}$$

The output can be changed to a variable duty cycle pulse generator by providing two feedback paths to the inverting input. The op amp chosen for this circuit should have a fairly high slew rate to provide the best square wave output.

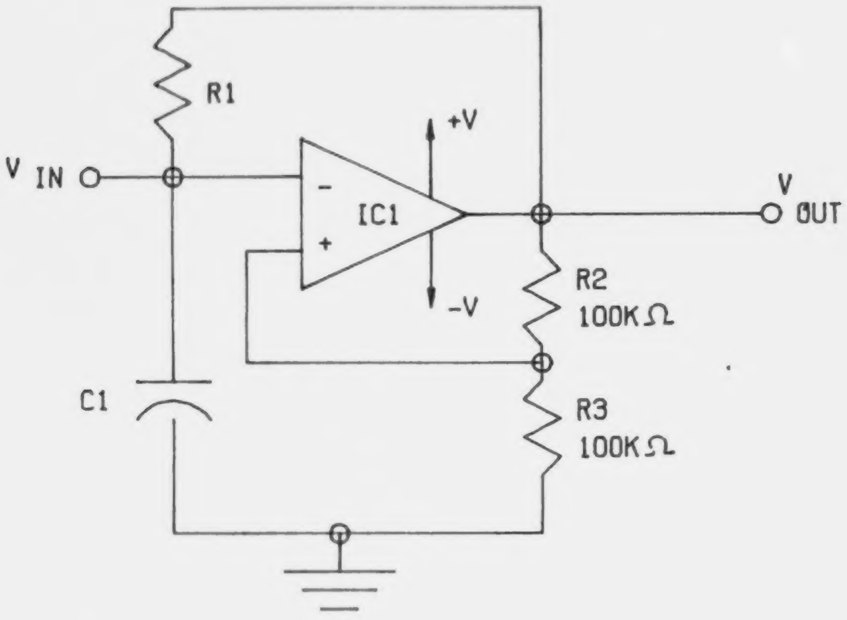

R1
+V
V IN
-
IC1
+
V OUT
-V
R2
100KΩ
C1
R3
100KΩ

Figure E 7.1-2

Figure E 7.1-3 is an example of an astable multivibrator built from two CMOS inverters. The frequency of operation is inversely proportional to the RC time constant. C_1 should be a non-polarized type of capacitor. Its value can range from pico farads to micro farads. The resistors can have any value from 47K ohms to 20 plus mega ohms. With these values the output frequency can vary from 1 hz to 1 Mhz. The value of R_2 must be kept large in relation to R_1. This type of astable will work quite well where critical timing is not important.

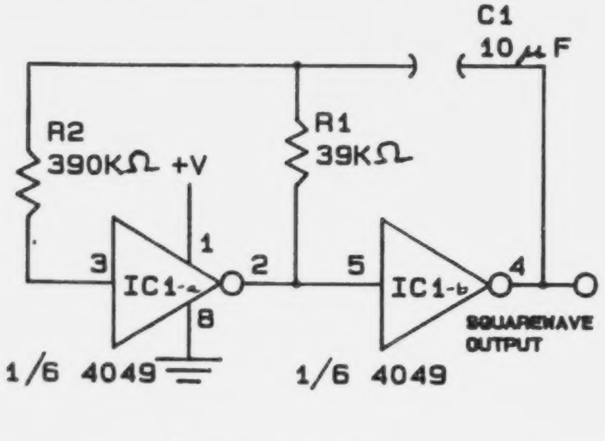

C1
10µF
R2
390KΩ
+V
R1
39KΩ
1
3
IC1-a
2
5
IC1-b
4
8
SQUAREWAVE OUTPUT
1/6 4049
1/6 4049

Figure E 7.1-3

INFORMATION SHEET E 7.1 CONT'D.

Figure E 7.1-4 is an example of a 555 integrated circuit timer used as an astable multivibrator. This IC is very rugged, and provides a stable output operating from a range of supply voltages.

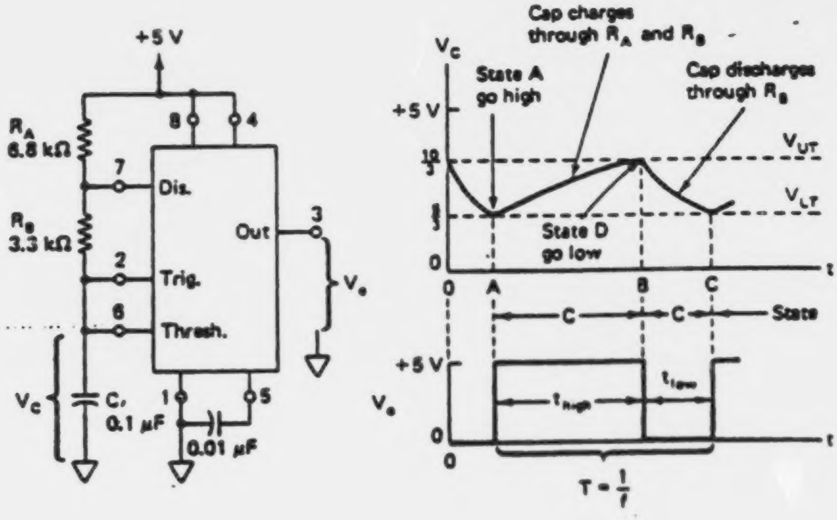

+5 V
R_A 6.8 kΩ
R_B 3.3 kΩ
8
4
7
Dis.
2
Trig.
6
Thresh.
Out
3
V_o
V_c
C, 0.1 µF
1
5
0.01 µF
Cap charges through R_A and R_B
V_c
State A go high
Cap discharges through R_B
+5 V
10/3
5/3
V_UT
V_LT
State D go low
0
t
0
A
B
C
C
C
State
+5 V
V_o
t_high
t_low
0
0
t
T = 1/f

Figure E 7.1-4

R_A, R_5 and C determine the frequency of operation. The frequency can be calculated using the formula,

$$F = \frac{1.44}{(R_A + 2R_3)C}.$$

The circuit above is operating at

$$F = \frac{1.44}{(6.8K\Omega + 2*3.3K\Omega)\ 0.1\,\mu F}$$

F 1075 hz. The period T=1/F=930 µsec.

The duty cycle for the circuit of figure 4 is calculated using the following:

$$D = \text{time low}/T \quad \text{or } D = \frac{R_B}{R_A = 2R_B};$$

Example: $D = \dfrac{3.3K\Omega}{6.8K\Omega + 2(3.3K)} = 0.25.$

This means the output is OFF, low, for approximately 25% of the time period T.

The 555 IC can also be used in the monostable mode of operation. Figure E 7.1-5 is an example. Many circuits need to be on for only a specific period of time. The monostable multivibrator circuit can provide the "one-shot" output for that period of required time. Figure E 7.1-5 shows the input "trigger" and the resulting output pulse. The time the output remains high is determined by R_A and C. This time can be calculated using the following formula:

$$t \text{ high} = 1.1 R_A C$$

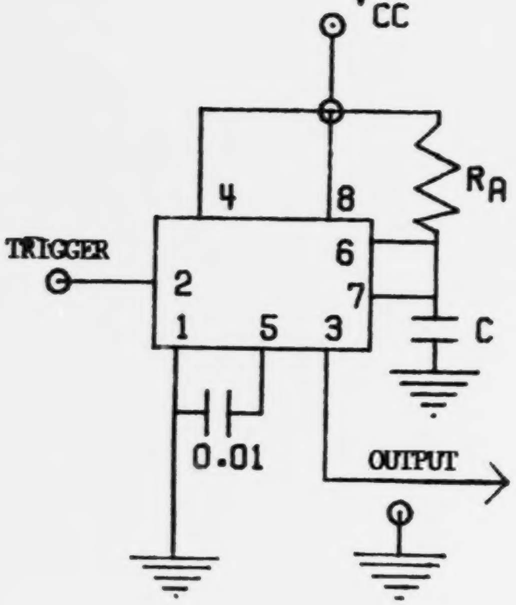

V_{CC}
4
8
R_A
TRIGGER
2
6
7
1
5
3
C
0.01
OUTPUT

Figure E7.1-5

Graphs like Figure E 7.1-6 are design aids found in any data book and allow quick determination of R_A and C for a specific output. The diagram of Figure E 7.1-6 is used as follows: Let's say you want an output pulse that has a duration of 1 millisecond. Pick a stock capacitor value of 0.1 μ farrad. Locate the 1 ms duration time on the horizontal portion of the graph. Trace upward until the 0.1 μ vertical line is intersected. Look to the nearest diagonal line. This is your approximate value of R_A. On our example it would be slightly below 10 K ohms. If you need an exact value for R_A use the formula:

$$RA = \frac{t \text{ high}}{1.1C} .$$

Take the following example:

$$R_A = \frac{1 \text{ m sec}}{1.1 \times .1 \mu F} = R_A = 9.1 \text{ K}\Omega .$$

One point of caution is to remember that the input pulse must be of a much smaller duration than the output pulse. A rule of thumb for this caution is to have the input trigger go from high to low and back in less time than the output pulse. Stated another way, the trigger input should not have a longer time period than the output pulse.

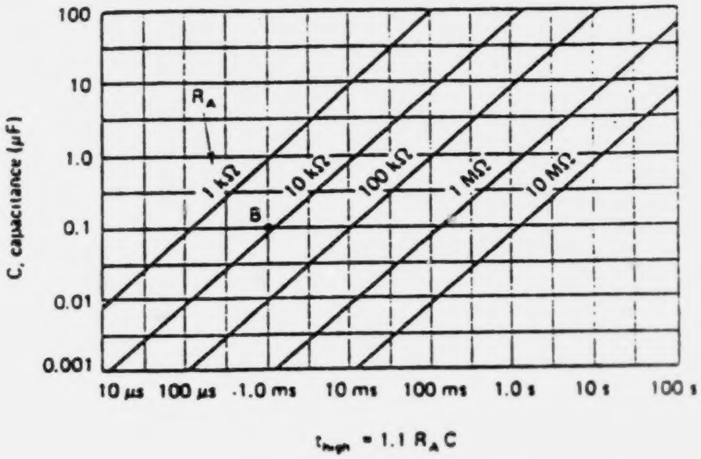
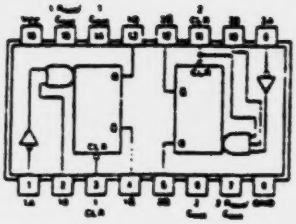
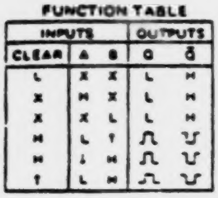


Figure E 7.1-6

Figure E 7.1-7 is an example of a TTL dual monostable and its corresponding truth table. The output pulse is controlled by an external resistor and capacitor on the inputs marked "R ext/ C ext-C ext."





FUNCTION TABLE

INPUTS			OUTPUTS	
CLEAR	A	B	Q	$\overline{Q}$
L	X	X	L	H
X	H	X	L	H
X	X	L	L	H
H	L	↑	⊓	⊔
H	↓	H	⊓	⊔
↑	L	H	⊓	⊔

Figure E 7.1-7

The output pulse, Tw, can be calculated using the following formula: $t_w \simeq 0.37 * R_t \ C_{ext}(1+0.7/R_t)$

An example would be as follows:

$$\begin{aligned} t_w &\simeq 0.37 * 10K * 0.1\,\mu F(1+0.7/10K\Omega) \\ &\simeq .37 \text{ milliseconds} \end{aligned}$$

This formula relates to a specific TTL device. If you are doing calculations, always refer to the manufacturer data for the specific device you are using. It should also be mentioned that not all oscillators are RC controlled. Figure E 7.1-8 is an example of a crystal-controlled CMOS oscillator. The advantage of the crystal-controlled oscillator is its stability. The main disadvantage is the cost of the crystal.

Oscillator and multivibrator circuits are used extensively in electronics. This guide has only touched on a few of the many circuits. It would be to your advantage to investigate these circuits in greater depth.

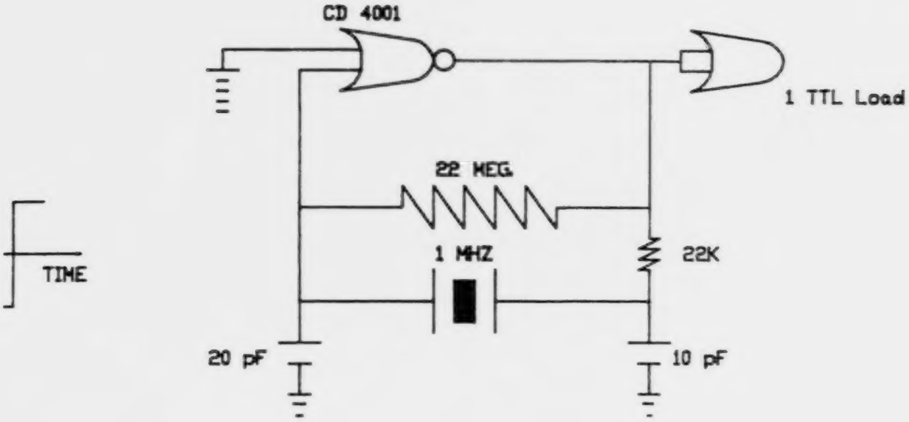

CD 4001
1 TTL Load
22 MEG
1 MHZ
22K
20 pF
10 pF
TIME

Figure E 7.1-8

ACTIVITY SHEET

E 7.2

MULTIVIBRATOR CIRCUITS

1. Define the following terms:
   A. Multivibrator:

   B. Astable:

   C. Monostable:

   D. RC time constant:

   E. Period:

2. Draw the schematic diagram for an astable multivibrator, using a 555 timer IC.

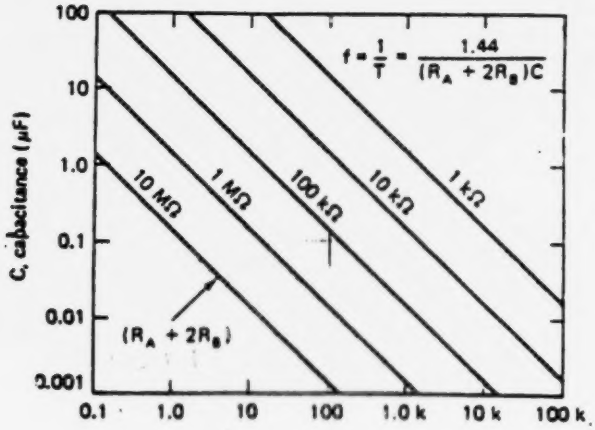
3. Using Figure E 7.2-1, calculate the nature of R_A and R_B and C for the following frequencies:
   A. F = 100 hz

   B. F = 1 hz

   C. F = 1 Khz

   D. F = 10 Khz

Figure E 7.2-1:



4. Draw the schematic diagram for a monostable multivibrator using a 555 IC.

5. Calculate the value of R_A and C for the following:
A. Pulse width = 100 ms R_A _______ C ______

B. Pulse width = 10 ms R_A ______ C ______

6. Draw the schematic diagram for a monostable multivibrator using a 74123 IC.

7. Calculate the values of C and R for the following:
(Consult TTL data book)
A. 1 ms pulse C __________ R __________

B. 2 ms pulse C _________ R __________

ACTIVITY SHEET E 7.2

ANSWER SHEET

1. A. See information sheet.

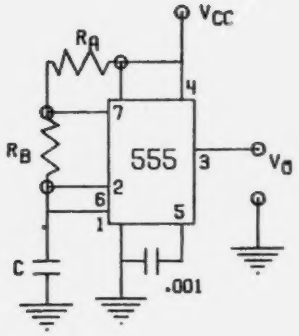
   B. " "

   C. " "

   D. " "

   E. " "

2.


Vcc
RA
4
7
555
3
Vo
RB
2
6
5
1
C
.001

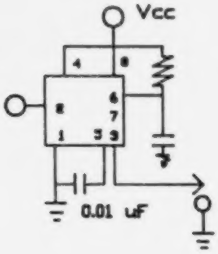
3. A. F= 100 hz; let C= 1 µf
   R_A + 2RB = 14,400Ω

   B. F=1 hz; let C=10 µf
   R_A + 2RB = 144,000Ω

   C. F=1 Khz; let C=.1 µf
   R_A + 2RB = 1,440Ω

   D. F=10 Khz; C=.1 µf
   R_A + 2RB = 1,440Ω

4.

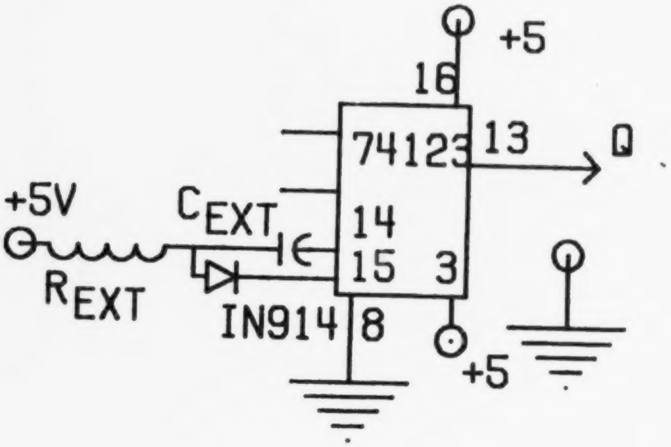

Vcc
4
8
2
6
7
1
5
3
0.01 uF

ACTIVITY SHEET E 7.2 CONT'D.

5. A. 100 ms $R_A \simeq 910\Omega$ let C=.1 μf

   B. 10 ms RA $\simeq$ 91 KΩ let C=.1 μf

6.


+5
16
74123
13
Q
+5V
C_{EXT}
14
15
3
R_{EXT}
IN914
8
+5

7. A. 1ms; let R= 47KΩ
   C$\simeq$ 58 pF

   B. .2ms; let R = 10 KΩ
   C$\simeq$ 54 pF

PROGRAM: ELECTRONICS

TASK: MULTIVIBRATORS

TASK #: E 7.3

PERFORMANCE/ PRODUCT CHECKLIST

STUDENT'S NAME________________________ EVALUATION SITE___________

EVALUATOR'S NAME____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT____________

TERMINAL PERFORMANCE OBJECTIVE:

Aanalyze, construct, and troubleshoot basic multivator circuits.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation contact your instructor. You must score at least 6 out of 7 points or 80% for mastery. Critical items are marked with an asterisk(*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 7 points or 80% and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

MULTIVIBRATORS

E 7.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
1.	Was the circuit wired according to the schematic?	Y	N
*2.	Does the circuit function properly?	Y	N
*3.	Was necessary data recorded?	Y	N
4.	Was the correct equipment used?	Y	N
5.	Was the equipment used properly?	Y	N
*6.	Were safety precautions followed?	Y	N
*7.	Was equipment returned to proper storage area?	Y	N

TOTAL POINTS POSSIBLE ___

POINTS NEEDED FOR MASTERY ___

SCORE ___

EXAM E 7.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on multivibrator circuits. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the questions or completes the statement correctly. Place the letter associated with that choice (A, B, C, D) in the numbered blank space on your ANSWER SHEET. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer 8 out of 10 items correctly, 80%.

EXAM E 7.4 CONT'D.

1. A 555 Ic is wired as an astable multivibrator. R_A is equal to 10 KΩ . RB is equal to 22KΩ. C is equal to 1 μF. The frequency of operation is ______________.

   A. 270 hz

   B. 2.7 hz

   C. 27 hz

   D. 2.7 Mhz

$$f = \frac{1.44}{(R_1+2R_2)C_1}$$

2. The duty cycle for the circuit of question number 1 would be ____________.

   A. 69%

   B. 82%

   C. 50%

   D. 25%

$$D = \frac{R_2}{R_1 + R_2}$$

3. The period of the output frequency of the circuit of question number 1 would be approximately ____________.

   A. 22 mS

   B. 2.2 mS

   C. 38 mS

   D. 22 mS

$$T = .693\ (R_1 + 2R_2)\ C_1$$

4. If the value of capacitor in question 1 was changed to .022 F, the new frequency of operation would be approximately ____________.

   A. 1 Khz

   B. 1.2 Khz

   C. 12.2 Khz

   D. 470 hz

$$f = \frac{1.44}{(R_1+2R_2)C_1}$$

5. Would this change affect the duty cycle?

   A. Yes

   B. No

6. A 555 is wired as a monostable multivibrator. R_A is equal to 10 KΩ . C is equal to .1 μF. The output pulse width is approximately ____________.

   A. 1 mS

   B. 2 mS

   C. .1 mS

   D. 10 mS

$T = R_1 \times C_1$

7. The trigger input to the circuit of question 6 can be ____________.

   A. greater than the output pulse

   B. less than the output pulse

8. The formula for calculating the pulse width of a monostable using a 555 IC is:

   A. $R_B/R_A + 2R_B$

   B. 1/F

   C. $1.44/(R_A + 2RB)C$

   D. 1.1 RAC

9. Refer to Figure E 7.4-1. The output frequency is controlled by ____________.

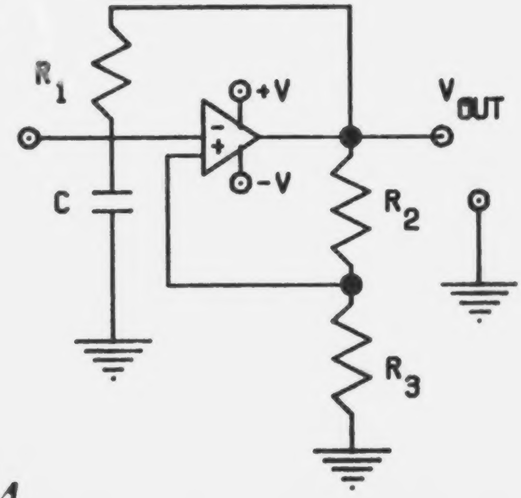
   A. R_2 and R_3

   B. R_1 and C

   C. R_3 and C

   D. R_2 and C

Figure E 7.4-1:



10. A crystal-controlled multivibrator is ____________.

A. more accurate than an RC-controlled multivibrator

B. less accurate than an RC-controlled multivibrator

EXAM KEY E 7.4

1. C
2. A
3. C
4. B
5. B
6. A
7. B
8. D
9. B
10. A

ELECTRONICS

ANALYZING DIGITAL ELECTRONIC CIRCUITS

E 8: BASIC COUNTER CIRCUITS

TASK: Analyze, construct, and troubleshoot basic counter circuits.

PURPOSE: In digital circuits, and even analog circuits, things have to be counted. This need is met by digital counting circuits; consequently, the electronics technician must be very familiar with their operation. After completing this learning guide you should be able to construct and troubleshoot basic digital counter circuits, and explain their operation.

OBJECTIVE: Given access to all necessary tools and equipment, you will analyze, construct, and troubleshoot basic counter circuits. To master this task you must score 80% on a written exam and performance checklist.

ESTIMATED CLASS TIME: 12 TO 15 HOURS

BASIC COUNTER CIRCUITS

LEARNING STEPS

E 8

READ: Information Sheet E 8.1, "Counters."

READ: Information on counters in one or more resources below.

COMPLETE: Activity Sheet E 8.2 on "Counters."

COMPLETE: Lab performance on counters. Contact your instructor.

REVIEW: All the material covered in this learning guide.

COMPLETE: Performance Checklist E 8.3. Contact your instructor.

COMPLETE: Written Exam E 8.4. Contact your instructor.

BASIC COUNTER CIRCUITS

RESOURCES

E 8

1. CMOS DATA MANUAL (Motorola).
2. Brey, DIGITAL ELECTRONICS (Bobbs-Merrill, 1984).
3. Tokheim, DIGITAL ELECTRONICS TEXT AND ACTIVITY MANUAL (McGraw-Hill, 1984).
4. Tocci, DIGITAL SYSTEMS (Prentice-Hall, 1984).
5. DIGITAL TECHNIQUES STUDENT WORKBOOK (Heath Co., 1981).
6. Williams, DIGITAL TECHNOLOGY (SRA, 1982). 2nd Ed.
7. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Ed.
8. Texas Instrument TTL DATA MANUAL.

INFORMATION SHEET

E 8.1

COUNTERS

Almost all digital systems contain some form of counter. These counter circuits may consist of several flip-flops wired together to form a simple counter, or there may be several specialized integrated circuit counters configured into a complicated counting system. This guide will cover the basics of counters. Listed below are some of the terms encountered when discussing digital counters. Study these terms and become familiar with their meaning.

Counter:	A circuit designed to count input pulses. A device which can be set to an initial number and increased or decreased by applying clock pulses to its input.
Modulus:	Refers to the number of counting states a counter displays before it repeats itself.
Ripple Counter:	A binary counting system in which the flip-flops are connected in series. When the first flip-flop changes its output, it affects the second, which affects the third, and so on. Sometimes called asynchronous counter.
Synchronous Counter:	A counter having all flip-flops clock inputs tied together to a common clock input.
Programmable Counter:	A counter whose modulus can be loaded and controlled by internal gating.
Decade Counter:	A counter that has ten states.
Down Counter:	A type of counter that counts in a descending order.
Ring Counter:	Serial shift register with recirculation, serial output connected back to serial input. One of the simplest counters and requires no decoding.
Johnson Counter:	Similar to the ring counter except that complement of the output is fed back.

The basic element of the counter is the flip-flop. Usually the flip-flop is a JK with the inputs J and K tied high, logic 1. Figure E 8.1-1 is an example of this toggle type flip-flop. Notice the output changes only once, while the input changes twice. This is a characteristic of what is called a "T" flip-flop. If a string of these flip-flops were tied together as in Figure E 8.1-2, a 3-bit asynchronous up counter would be formed.

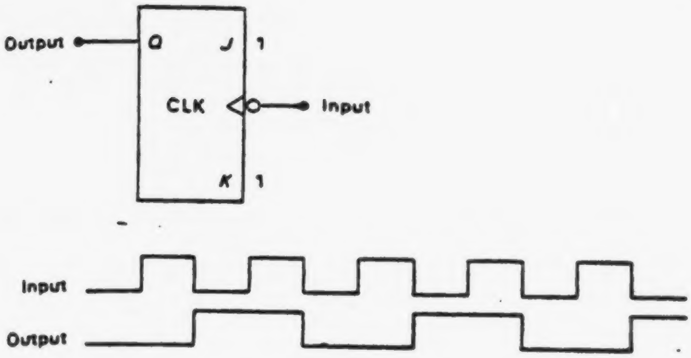


Figure E 8.1-1

Figure E 8.1-2 is called a 3-bit counter because it has three outputs. It is an asynchronous counter because the flip-flops do not share a common clock. The output of one flip-flop is the clock for the next flip-flop. It is classified as an up counter because the Q output is fed to the input of the next flip-flop. The timing diagram displays the way the count is "rippled" through the counter. Note the first dashed line marked (1). There have been two clock pulses and the counter output is 10 (decimal 2). Note the second dashed line (2). There have been seven clock pulses and the counter output is 111 (decimal 7).

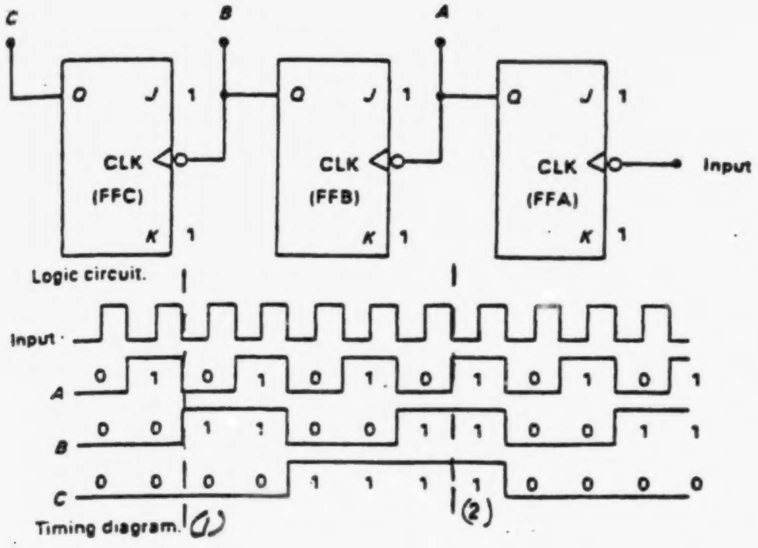

C
B
A
Q
J
1
CLK
(FFC)
K
(FFB)
(FFA)
Input
Logic circuit.
A
B
C
0 1 0 1 0 1 0 1 0 1 0 1
0 0 1 1 0 0 1 1 0 0 1 1
0 0 0 0 1 1 1 1 0 0 0 0
Timing diagram.
(1)
(2)

Figure E 8.1-2

Asynchronous down counters are built much like up counters with the exception of the outputs. Instead of using the Q to feed the next input, the Q is fed into the next flip-flop's input. The count starts with all outputs at a logic 1 and counts down to zero, and then up to all ones. Figure E 8.1-3 is an example of a two-bit asynchronous down counter. A counter could be made to count either up or down by simply having a gate or switch select

Q or $\overline{Q}$.

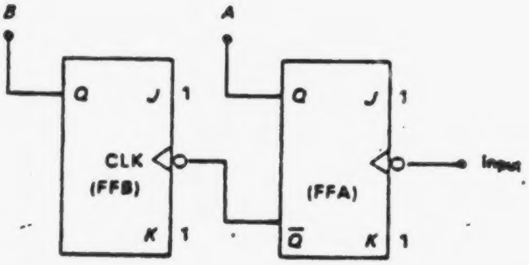
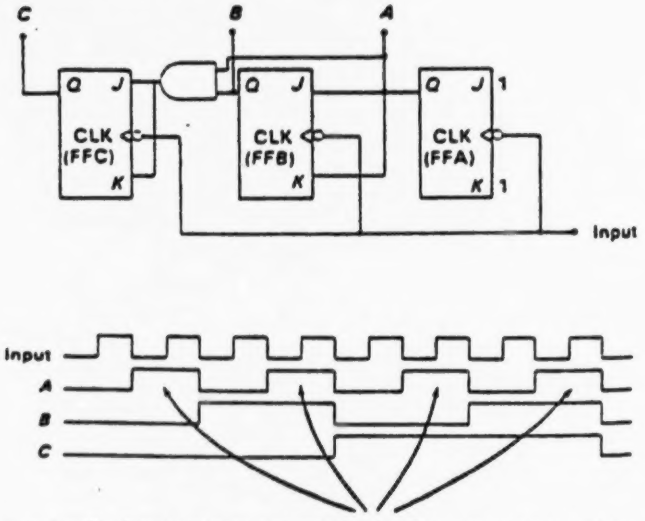

B
A
Q
J
1
CLK
(FFB)
K
(FFA)
$\overline{Q}$
Input

Figure E 8.1-3

Asynchronous counters are easy to build and work quite well where speed is not a concern. However, when speed is important the synchronous counter is best suited. Figure E 8.1-4 is an example of a 3-bit synchronous up counter. Notice that all the flip-flops share a common clock. Also note the addition of the AND gate. The timing diagram of Figure E 8.1-4 explains the action of the AND gate. Notice that a flip-flop C will not toggle high until the output of the AND gate is high, which means the inputs from flip-flops A and B must be high. The entire counter is synchronous by the clock.


C
B
A
Q J
CLK
(FFC)
K
Q J
CLK
(FFB)
K
Q J 1
CLK
(FFA)
K 1
Input
Input
A
B
C

A logic 1 on flip-flop A produces change in flip-flop B on the next clock pulse

Figure E 8.1-4

Not all counters have to be natural binary counters, that is counters which have 2 different states. Counters with a different modulus can be created by using gated asynchronous counters. Figure E 8.1-5 is an example of modulus 10 counter.

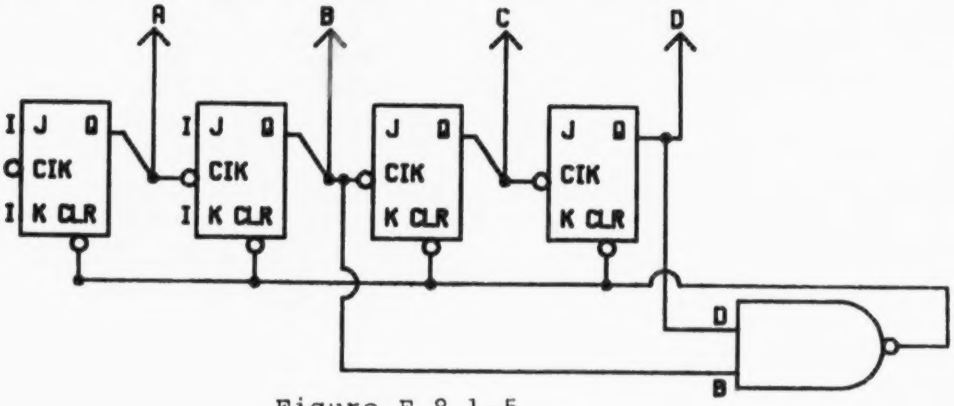

A
B
C
D
I J Q
CIK
I K CLR
I J Q
CIK
I K CLR
J Q
CIK
K CLR
J Q
CIK
K CLR
D
B

Figure E 8.1-5

The counter will count from 0000 to 1001 and then repeat. Its modulus is set to 10. The operation is easy to understand if you ask yourself "why doesn't it count to 1010 (decimal 10)." The inputs from B and D are fed to a NAND gate. When the B and D input try to go to 1, the NAND gate outputs a logic low, which clears the counter back to zero. With the proper gating any modulus can be built.

All of the counters covered so far have been built from discrete JK flip-flops. If all counters had to be built this way, much of the printed circuit board would be occupied by JK flip-flops. Manufacturers, of course, provide counters in a variety of types and moduli. Check a CMOS and TTL data book to see how many different counters are available for a designer. These units are called IC counters, because the counter is an integrated circuit, built specifically as a counter.

Figure E 8.1-6 is an example of decade counters cascaded together to make one counter with a modulus of 60. Note that one of the decade counters is not configured as a decade counter, but as a mod 6, or divide-by-6 counter. Often counters are made to have more than one count length. R_0 (1) and R_0(2) are inputs to an internal gate. These inputs are connected to BCD inputs 2 and 4. When the count tries to go to 0110, the gate will reset the counter. Note that the divide by 10 counter forms the least significant digit (LSD), and its output feeds the clock. The divide-by-6 counter forms the most significant digit.

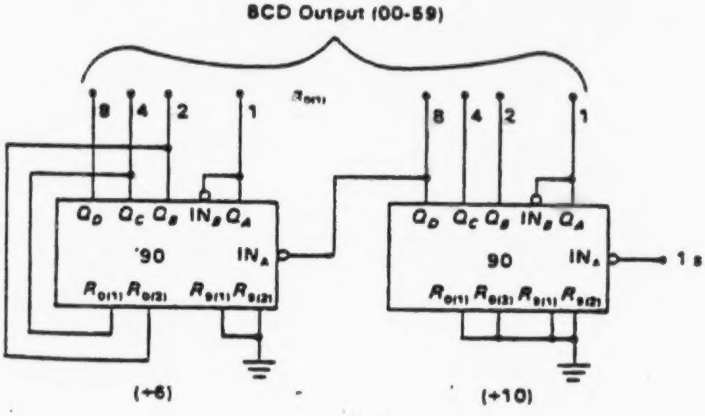

BCD Output (00-59)
$R_{0(1)}$
8
4
2
1
8
4
2
1
Q_D Q_C Q_B IN_B Q_A
'90
IN_A
$R_{0(1)}$ $R_{0(2)}$ $R_{9(1)}$ $R_{9(2)}$
Q_D Q_C Q_B IN_B Q_A
90
IN_A
$R_{0(1)}$ $R_{0(2)}$ $R_{9(1)}$ $R_{9(2)}$
1 s
(÷6)
(÷10)

Figure E 8.1-6

As integrated circuit fabrication techniques have advanced, so has the complexity of the circuits. Modern counters come in dual and quad units. They can be programmed to count up or down and have different moduli. Figure E 8.1-7 in an example of a programmable counter. Note the data inputs used to load data for an up count. Ripple-carry output is used for cascading to another counter. Enable P and T are high active inputs to enable the counter. Load is a low active input used to strobe data from inputs into the counter.

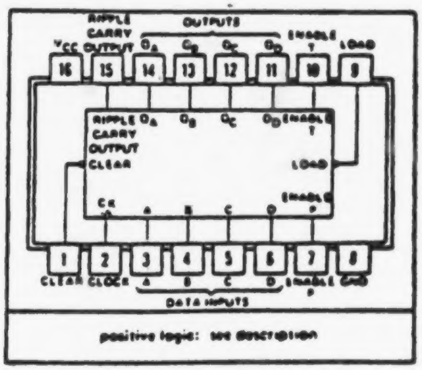

RIPPLE CARRY OUTPUT
OUTPUTS
ENABLE T
LOAD
V_{CC}
Q_A
Q_B
Q_C
Q_D
16
15
14
13
12
11
10
9
RIPPLE CARRY OUTPUT
CLEAR
CK
A
B
C
D
ENABLE T
LOAD
ENABLE P
1
2
3
4
5
6
7
8
CLEAR
CLOCK
A
B
C
D
ENABLE P
GND
DATA INPUTS
positive logic: see description

Figure E 8.1-7

Figure E 8.1-8 is an example of a new divide by CMOS counter. This is one of a family of five counters which can be selected for almost any timing need. These counters are used to divide an input frequency to a lower frequency. An example of one class in the family is a divide-by-60 counter. This counter is used to divide the line frequency, 60 hz, into a 1 hz output. These counters are unique in that not only do they count, but they condition the input sine wave into a pulse. Because these devices use CMOS technology they are high in noise immunity, low in power dissipation, and can operate from a variety of power supply voltages.

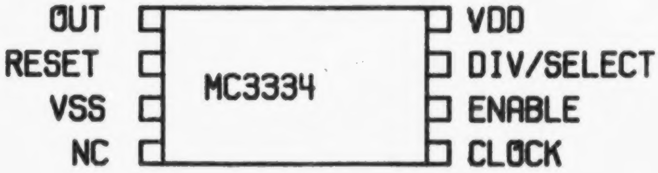

OUT
RESET
VSS
NC
MC3334
VDD
DIV/SELECT
ENABLE
CLOCK

Figure E 8.1-8

INFORMATION SHEET E 8.1 CONT'D.

Counters and their applications are limited only by the designer's imagination. As an electronics technician you will be working on electrical systems which will have many counter circuits. The better understanding you have of counters the easier troubleshooting these circuits will be.

ACTIVITY SHEET

E 8.2

COUNTERS

1. How many different counting states do each of the following binary counters contain ________?

   A. 3-bit

   B. 7-bit

   C. 9-bit

2. Draw a 4-bit asynchronous up counter.

3. Draw a 2-bit asynchronous down counter.

4. Draw a 3-bit synchronous up/down counter.

5. Draw the truth table for a 4-bit up counter.

6. Is a ripple counter an asynchronous counter?

7. Draw a mod-6 up counter. Draw a truth table for its output.

8. Cascade two 7490's to make a 0-59 up counter.

9. Refer to Figure E 8.2-1 to answer the following questions:

ACTIVITY SHEET E 8.2 CONT'D.

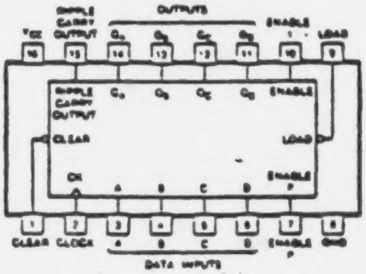

VCC
RIPPLE CARRY OUTPUT
OUTPUTS
Q_A
Q_B
Q_C
Q_D
ENABLE T
LOAD
16
15
14
13
12
11
10
9
RIPPLE CARRY OUTPUT
CLEAR
CK
ENABLE
LOAD
ENABLE P
A
B
C
D
1
2
3
4
5
6
7
8
CLEAR
CLOCK
A
B
C
D
ENABLE P
GND
DATA INPUTS

Figure E 8.2-1

A. Is clear high or low active?

B. What is the purpose of the data inputs?

C. What input is used to put data into the counter? Is is high or low active?

D. What is the purpose of the ripple carry output?

E. Is this counter cascadable?

F. If this is an up counter, what will the output do after a clear pulse is applied to the counter?

10. Use a TTL data book and label these counters.

A. 7490

B. 7492

C. 7493

D. 74162

E. 74198

F. 74393

Use a CMOS data book and label these counters.

A. 4017

B. 4040

C. 4024

ACTIVITY SHEET E 8.2

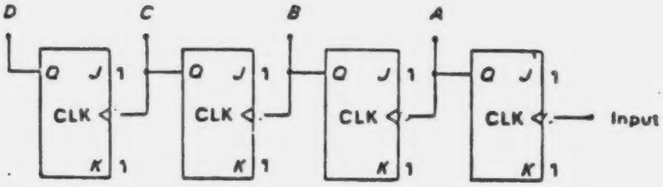
ANSWER SHEET

1. A. 3-bit = 2^3 = 8

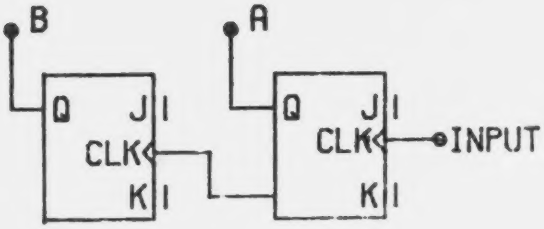
   B. 7-bit = 2^7 = 128

   C. 9-bit = 2^9 = 512

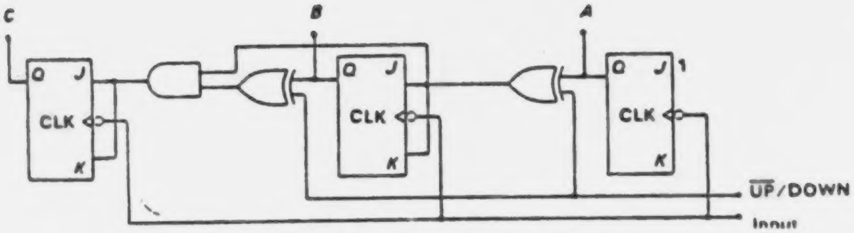
2.


D
C
B
A
Q
J
1
CLK
K
1
Input

3.


B
A
Q
J
1
CLK
K
1
INPUT

4.


C
B
A
Q
J
1
CLK
K
UP/DOWN
Input

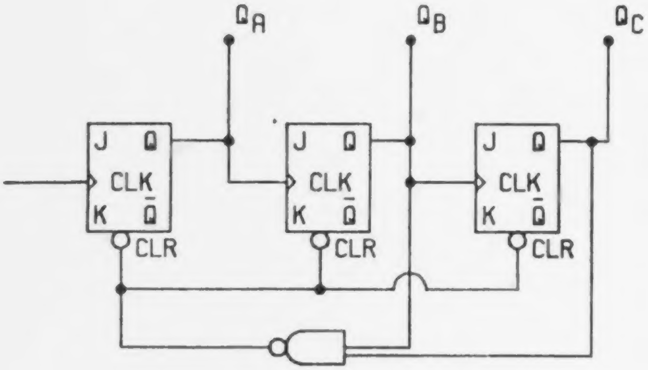
ACTIVITY SHEET E 8.2 CONT'D.

5.

COUNT	/ OUTPUT			
	Q_D	Q_C	Q_B	Q_A
0	L	L	L	L
1	L	L	L	H
2	L	L	H	L
3	L	L	H	H
4	L	H	L	L
5	L	H	L	H
6	L	H	H	L
7	L	H	H	H
8	H	L	L	L
9	H	L	L	H
10	H	L	H	L
11	H	L	H	H
12	H	H	L	L
13	H	H	L	H
14	H	H	H	L
15	H	H	H	H

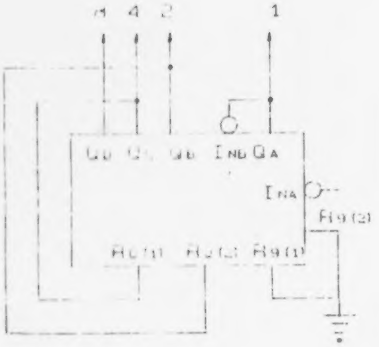
6. Yes. Ripple is just another term for asynchronous.

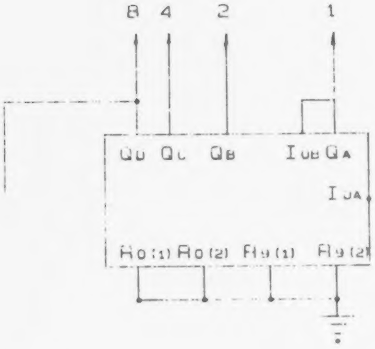
7.


QA
QB
QC
J
Q
CLK
K
Q̄
CLR
J
Q
CLK
K
Q̄
CLR
J
Q
CLK
K
Q̄
CLR

COUNT	Q_A	Q_B	Q_C
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1

8.


8
4
2
1
QD
QC
QB
INB
QA
INA
R9(2)
R0(1)
R0(2)
R9(1)


8
4
2
1
QD
QC
QB
INB
QA
INA
R0(1)
R0(2)
R9(1)
R9(2)

ACTIVITY SHEET E 8.2 CONT'D.

9. A. Low active--note the bubble.

B. Used to program the counter.

C. Load input. It is low active.

D. It outputs a high at the end of the count to trigger the next counter input.

E. Yes.

F. The counter will be cleared and all outputs will go low.

10. A. 7490--Decade counter

B. 7492--Divide-by-12 counter

C. 7493--4-bit binary counter

D. 74162--Up/down decade

E. 74393--Dual 4-bit binary

A. 4017--Decade counter/divider

B. 4040--12-bit binary counter

C. 4024--7-stage ripple counter

PROGRAM: ELECTRONICS

TASK: BASIC COUNTER CIRCUITS

TASK #: E 8.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME______________________ EVALUATION SITE___________

EVALUATOR'S NAME______________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT___________

PERFORMANCE OBJECTIVE:

Analyze, construct, and troubleshoot basic counter circuits.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out of 7 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 7 points or 80% and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

BASIC COUNTER CIRCUITS

E 8.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the circuit wired according to the schematic?	Y N
*2.	Does the circuit function properly?	Y N
*3.	Was necessary data recorded?	Y N
4.	Was the correct equipment used?	Y N
5.	Was the equipment used properly?	Y N
*6.	Were safety precautions followed?	Y N
*7.	Was equipment returned to proper storage area?	Y N

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

SCORE ____

EXAM E 8.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on counters. Each of the questions or incomplete statements is true or false. Place the letter associated with that choice (A or B) in the numbered blank space on your ANSWER SHEET. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer 12 out of 15 items correctly, 80%.

1. The modulus of a counter is equal to the number of different states of a counter.

   A. True
   B. False

2. A counter will multiply the input frequency by its modulus.

   A. True
   B. False

3. The maximum operating frequency of a counter is determined by the settling time of its flip-flops.

   A. True
   B. False

4. A decade counter is a modulus-10 counter.

   A. True
   B. False

5. An asynchronous down counter uses the Q output to feed the next input.

   A. True
   B. False

6. Asynchronous counters are faster than synchronous counters.

   A. True
   B. False

7. Figure E 8.4-1 is an example of a synchronous counter.

   A. True
   B. False

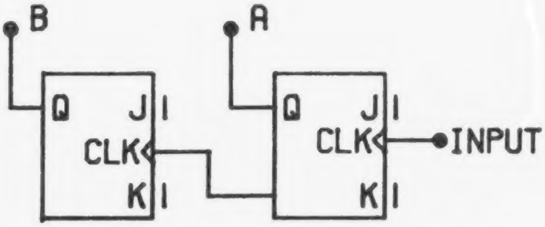
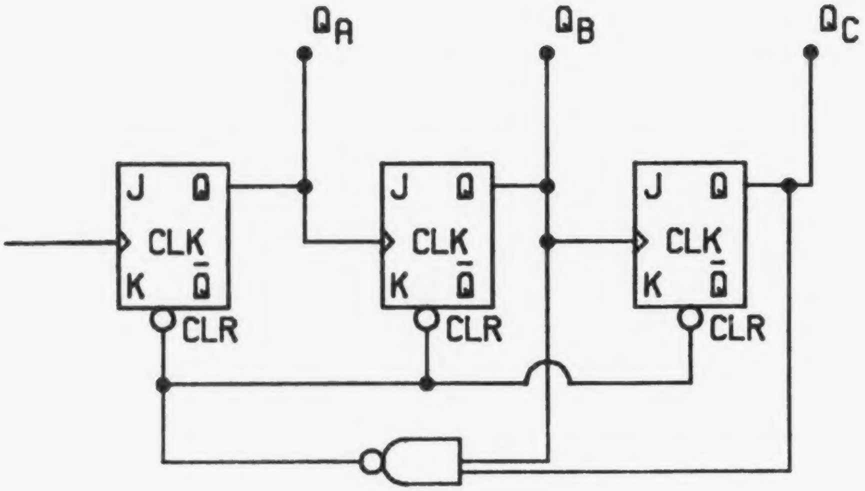


Figure E 8.4-1

8. Figure E 8.4-2 is an asynchronous counter.

A. True
B. False


Q_A
Q_B
Q_C
J
Q
CLK
K
$\bar{Q}$
CLR
J
Q
CLK
K
$\bar{Q}$
CLR
J
Q
CLK
K
$\bar{Q}$
CLR

COUNT	Q_A	Q_B	Q_C
0	0	0	0
1	0	0	1
2	0	1	0
3	0	1	1
4	1	0	0
5	1	0	1

Figure E 8.4-2

9. The modulus of the counter of Figure E 8.4-2 is four.

A. True
B. False

10. The clock input of figure two is a positive-edge triggered clock.

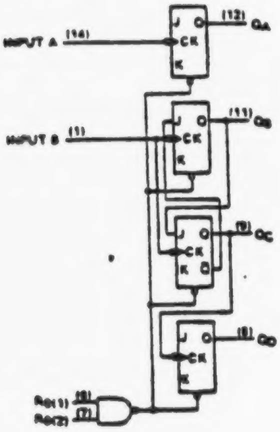
A. True
B. False

11. A logic one output from the NAND gate will clear the counter.

A. True
B. False

12. Refer to Figure E 8.4-3. The count output is for a divide by 12-counter.

A. True
B. False



COUNT	OUTPUT			
	Q_D	Q_C	Q_B	Q_A
0	L	L	L	L
1	L	L	L	H
2	L	L	H	L
3	L	L	H	H
4	L	H	L	L
5	L	H	L	H
6	H	L	L	L
7	H	L	L	H
8	H	L	H	L
9	H	L	H	H
10	H	H	L	L
11	H	H	L	H

'92A, 'LS92, '93A, 'L93, 'LS93
RESET/COUNT FUNCTION TABLE

RESET INPUTS		OUTPUT			
$R_{0(1)}$	$R_{0(2)}$	Q_D	Q_C	Q_B	Q_A
H	H	L	L	L	L
L	X	COUNT			
X	L	COUNT			

Figure E 8.4-3

13. The counter will work fine just the way it is configured.

A. True
B. False

14. If both R_0 inputs are brought high, the counter will clear.

A. True
B. False

15. The modulus of the counter in Figure E 8.4-3 cannot be changed.

A. True
B. False

EXAM KEY E 8.4 CONT'D

1. A

2. B

3. A

4. A

5. B

6. B

7. B

8. A

9. B

10. B

11. B

12. A

13. B

14. A

15. B

ELECTRONICS

ANALYZING DIGITAL ELECTRONIC CIRCUITS

E 9: SHIFT REGISTERS

TASK:	Analyze, construct, and troubleshoot basic shift register circuit.
PURPOSE:	Shift registers, or commonly, registers, are digital circuits used for temporary data storage. They are constructed from flip-flops. Shift registers have memory and shift characteristics. After completing this learning guide you should be able to construct shift register circuits, understand the characteristics of a register, and troubleshoot basic shift registers.
OBJECTIVE:	Given access to all necessary tools and equipment, you will analyze, construct, and troubleshoot basic shift reister circuits. To master this task you must score 80% on a written exam and performance checklist.

ESTIMATED CLASS TIME: 10 HOURS

SHIFT REGISTERS

LEARNING STEPS

E 9

READ:	Information Sheet E 9.1, "Shift Registers".
READ:	Information on shift registers in one or more resources listed below.
COMPLETE:	Activity sheet E 9.2 on "Shift Registers."
COMPLETE:	Lab performance on shift registers. Contact your instructor.
COMPLETE:	Performance Checklist E 9.3. Contact your instructor.
REVIEW:	All material covered by this learning guide.
COMPLETE:	Written Exam E 9.4. Contact your instructor.

SHIFT REGISTERS

RESOURCES

E 8

1. CMOS DATA MANUAL (Motorola).
2. Brey, DIGITAL ELECTRONICS (Bobbs-Merrill, 1984).
3. Tokheim, DIGITAL ELECTRONICS TEXT AND ACTIVITY MANUAL (McGraw-Hill, 1984).
4. Tocci, DIGITAL SYSTEMS (Prentice-Hall, 1984).
5. DIGITAL TECHNIQUES STUDENT WORKBOOK (Heath Co., 1981).
6. Williams, DIGITAL TECHNOLOGY (SRA, 1982). 2nd Ed.
7. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Ed.
8. Texas Instrument TTL DATA MANUAL.

INFORMATION SHEET

E 9.1

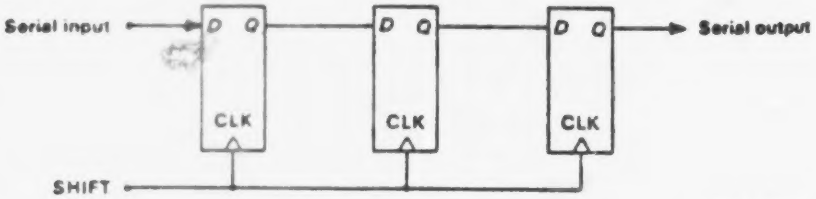
SHIFT REGISTERS

To understand the characteristics of a basic shift register, you must be able to comprehend some of the terminology associated with registers. Listed below are some shift register terms, study these until you have a good grasp of their meaning:

Byte-wide Register:	A register that can handle 8 bits of data.
FIFO:	First in, first out. The first bit of information in is the first bit out of a shift register.
Shift Register:	A register, composed of flip-flops, capable of temporarily storing data.
Serial Load:	A basic register which loads its data one bit at a time.
Parallel Load:	A shift register which can receive its data more than one bit at a time.
Recirculating:	A shift register feature which feeds the data back to the input from the last flip-flop. Data will recirculate in the register rather than being lost.
Universal Shift Register:	A register which is able to manipulate data in more than one manner.
Microprocessor Registers:	There are a variety of registers used inside and outside a microprocessor. They can be parallel or serial in nature and can handle their data by the bit or byte.

There are basically four types of shift registers, and each type is suited to a particular type of data manipulation. The four types of registers are serial-to-serial, parallel-to-parallel, serial-to-parallel, and parallel-to-serial. There is also a shift register called the Universal Shift Register which is capable of providing all four types of data transfers.

Start your investigation of shift registers with the serial to serial register. Figure E 9.1-1 is an example of a serial register built from D flip-flops. The operation of the serial register is easy to understand if you can recall the operation of a D flip-flop. The timing diagram of Figure E 9.1-1 is a visual representation of its operation. On the first clock pulse the data is low; this low is transferred to Q of the first flip-flop. On the second clock pulse, the data is high on the input, and the first low is shifted to the Q of the second flip-flop. The third clock pulse, transfers the first low to the third flip-flop. The fourth pulse moves the high that was input on the second clock pulse to the output of the last flip-flop. It should be apparent this is not a recirculating type of flip-flop, because the data is lost after it leaves the last flip-flop. As practice, imagine the procedure required to load the register with 101.



Logic circuit

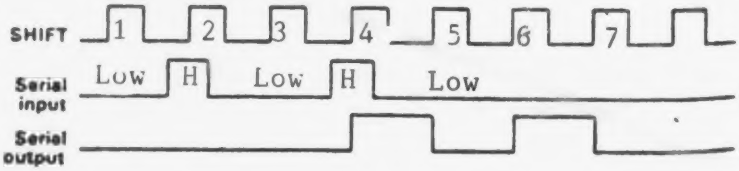


Figure E 9.1-1

A serial-to-parallel shift register is nothing more than a serial register with the outputs brought out to allow viewing the data. Figure E 9.1-2 is an example of a serial-to-parallel register. This register shifts the data from right to left with a slight modification the data transfer could be from left to right. Many serial registers are classified by how they transfer the data.

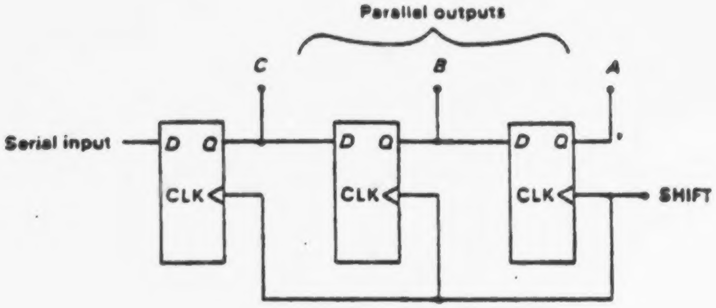

Parallel outputs
C
B
A
Serial input
D Q
CLK
SHIFT

Figure E 9.1-2

A parallel-loaded serial output, is another type of shift register. In this type of register the data is loaded on the parallel inputs, and removed on the serial output. The parallel data is loaded via NAND gates. The output of each gate is fed to the preset of each flip-flop, which sets the parallel data on each Q. The output will be shifted one bit at a time to the right. The timing diagram illustrates the operation of the register.

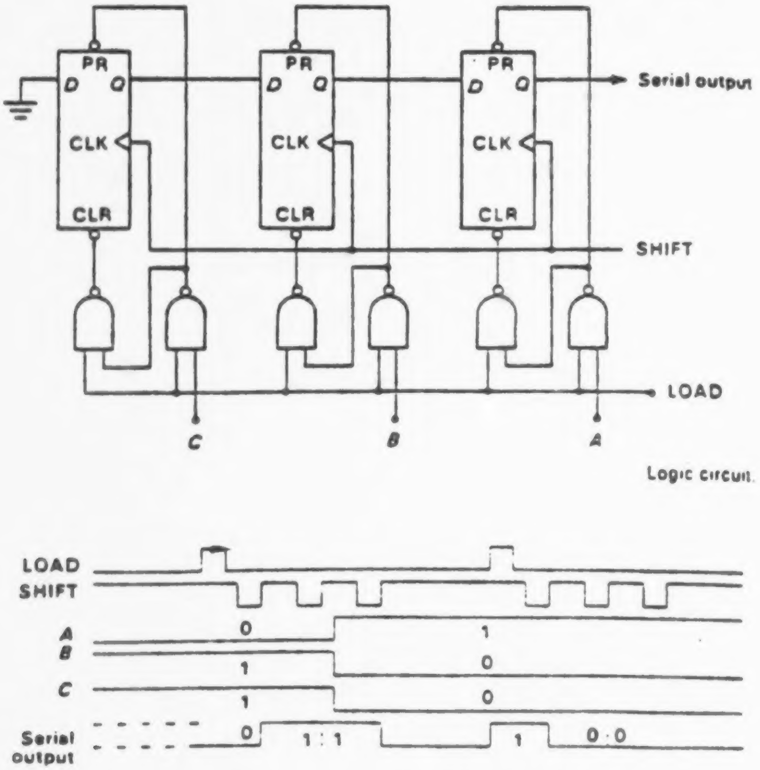

PR
D Q
CLK
CLR
Serial output
SHIFT
LOAD
C
B
A
Logic circuit
LOAD
SHIFT
A
B
C
Serial output
0
1
1
0
1
1
0
0
0 1 1 1 1 0 0

Figure E 9.1-3

The fourth shift register is a parallel-in parallel-out register. Unlike the last register this one uses no gating to load the data; instead the clock inputs are connected in parallel and fed to the load line. The operation of this register is illustrated by Figure E 9.1-4. Look at the timing diagram of Figure E 9.1-4, and note that the clock strobes the data from the inputs onto the outputs. The length of this register is not limited to four bits; it can be configured to any bit length desired. The parallel-to-parallel register is often configured as a latch, in that its load line is a strobe input and is used to hold data for temporary use. Registers of this type are usually 4 bits or 8 bits wide.

A special integrated circuit register, sometimes called the universal register provides a register which will handle data in more than one configuration. It has special inputs called mode controls which allow the register to be programmed. The register is in the TTL family and is called a 74194 universal shift register.

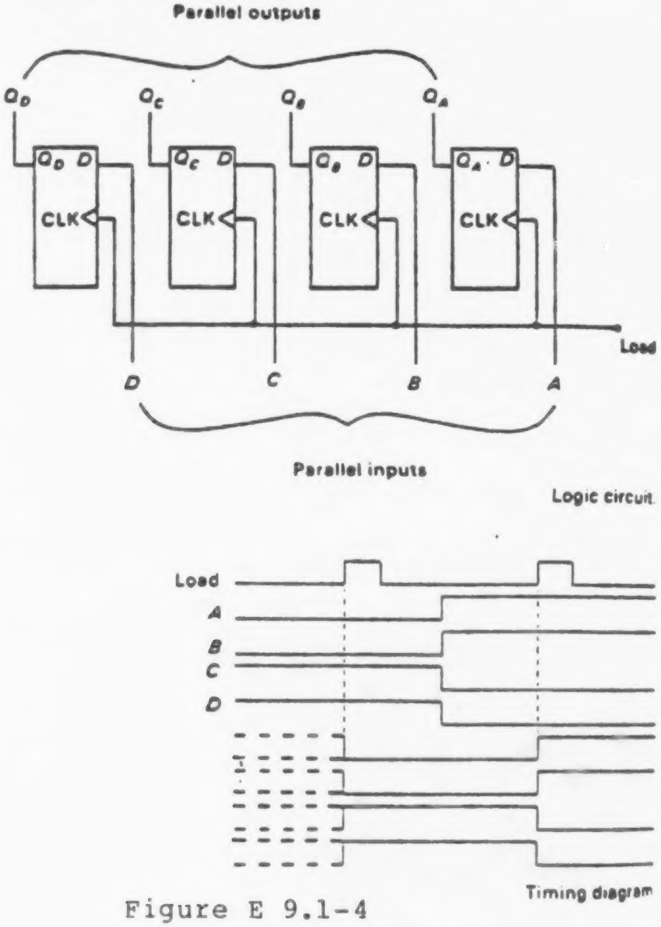
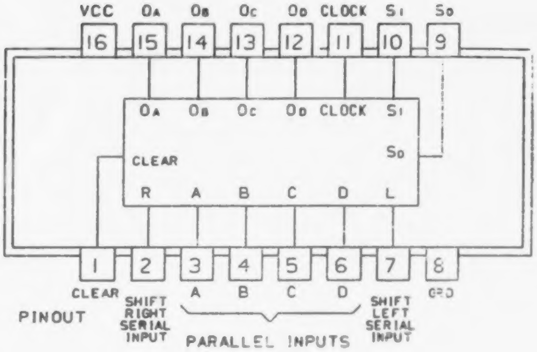

Parallel outputs
Q_D
Q_C
Q_B
Q_A
Q_D D
Q_C D
Q_B D
Q_A D
CLK
CLK
CLK
CLK
Load
D
C
B
A
Parallel inputs
Logic circuit
Load
A
B
C
D
Timing diagram

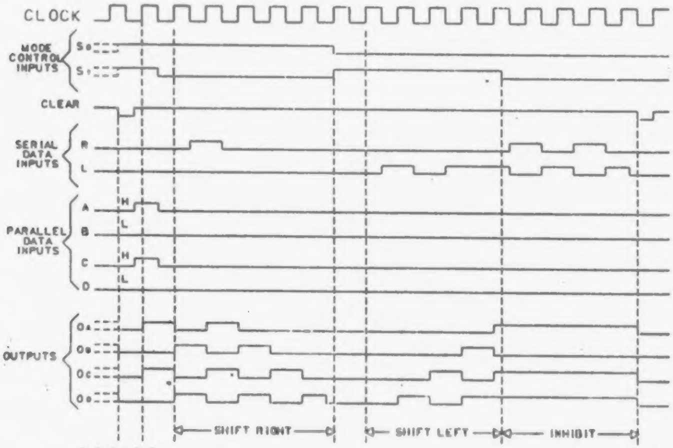
Figure E 9.1-4

Figure E 9.1-5 illustrates a pinout, timing diagram, and mode control table for the 74194. To use this device as a parallel-in parallel-out register set both mode control lines high, present data on inputs and strobe the clock. Look at the timing diagram for an illustration of how the other modes are set up and used. The universal shift registers can be cascaded together to provide a register 8 bits long if needed. It can also be constructed into a recirculating register by taking the last output and feeding back into the shift right serial input of the first flip-flop.


VCC
QA
QB
QC
QD
CLOCK
S1
S0
16
15
14
13
12
11
10
9
QA
QB
QC
QD
CLOCK
S1
CLEAR
S0
R
A
B
C
D
L
1
2
3
4
5
6
7
8
CLEAR
SHIFT RIGHT SERIAL INPUT
A
B
C
D
PARALLEL INPUTS
SHIFT LEFT SERIAL INPUT
GND
PINOUT

MODE CONTROL

PARALLEL LOAD	$S_0=1, S_1=1$
SHIFT RIGHT	$S_0=1, S_1=0$
SHIFT LEFT	$S_0=0, S_1=1$
INHIBIT	$S_0=0, S_1=0$


CLOCK
MODE CONTROL INPUTS
S0
S1
CLEAR
SERIAL DATA INPUTS
R
L
PARALLEL DATA INPUTS
A
B
C
D
H
L
H
L
OUTPUTS
QA
QB
QC
QD
SHIFT RIGHT
SHIFT LEFT
INHIBIT
CLEAR
LOAD
CLEAR

TIMING DIAGRAM

Figure E 9.1-5

There are many applications and types of shift registers which have not been covered in this learning guide. Use TTL and CMOS data books to see how many shift registers you can find.

ACTIVITY SHEET

E 9.2

SHIFT REGISTERS

1. List four configurations for shift registers.

   A.

   B.

   C.

   D.

2. Draw a serial-right to parallel register. Use J-K flip-flops.

3. Draw a parallel-to-serial shift-left register, using D-type flip-flops.

4. In CMOS and TTL data books look up and describe these shift registers.

   A. 4035

   B. 4014

   C. 4015

   D. 4194

   E. 74164

   F. 74194

   G. 74174

ACTIVITY SHEET E 9.2 CONT'D.

5. Draw a 74194 shift register in the shift-right position and in shift-left position (serial load).

6. Using two 74194's draw a schematic of an 8-bit parallel load/shift-right register with recirculation.

ACTIVITY SHEET E 9.2

ANSWER SHEET

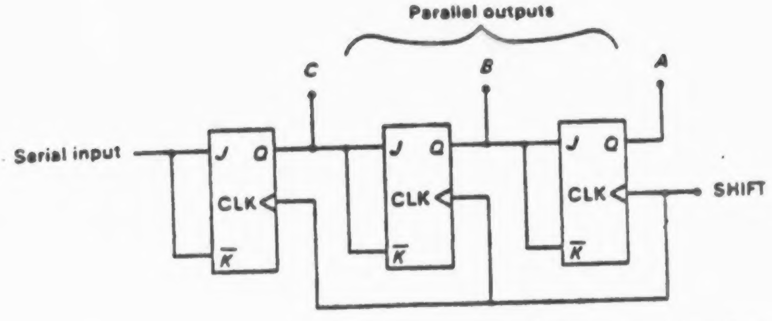
1. A. serial-to-serial

   B. serial-to-parallel

   C. parallel-to-serial

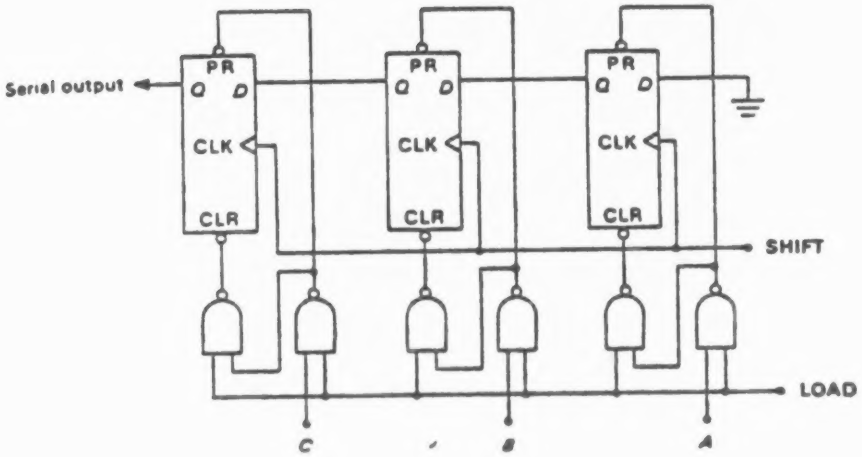
   D. parallel-to-parallel

2.


Parallel outputs
C
B
A
Serial input
J
Q
CLK
K̄
J
Q
CLK
K̄
J
Q
CLK
K̄
SHIFT

b. $J\bar{K}$ serial shift-right register.

3.


Serial output
PR
Q
D
CLK
CLR
PR
Q
D
CLK
CLR
PR
Q
D
CLK
CLR
SHIFT
LOAD
C
B
A

ACTIVITY SHEET E 9.2 CONT'D.

4. A. 4035--4-bit parallel-in/parallel-out

B. 4014--8-bit static shift register

C. 4015--dual 4-bit static

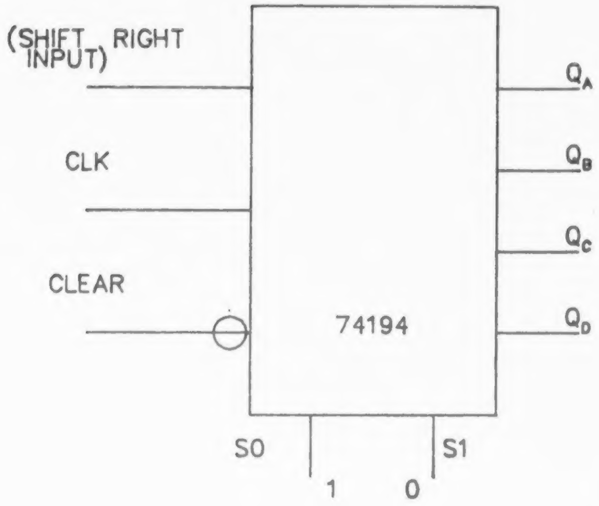
D. 4194--4-bit bidirectional universal

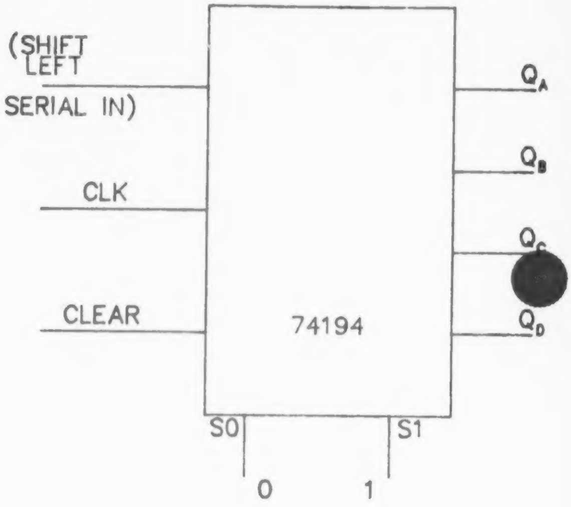
E. 74164--8-bit serial-in/parallel out

F. 74194--4-bit universal

G. 74174--Hex D flip-flop (could be used as a register)

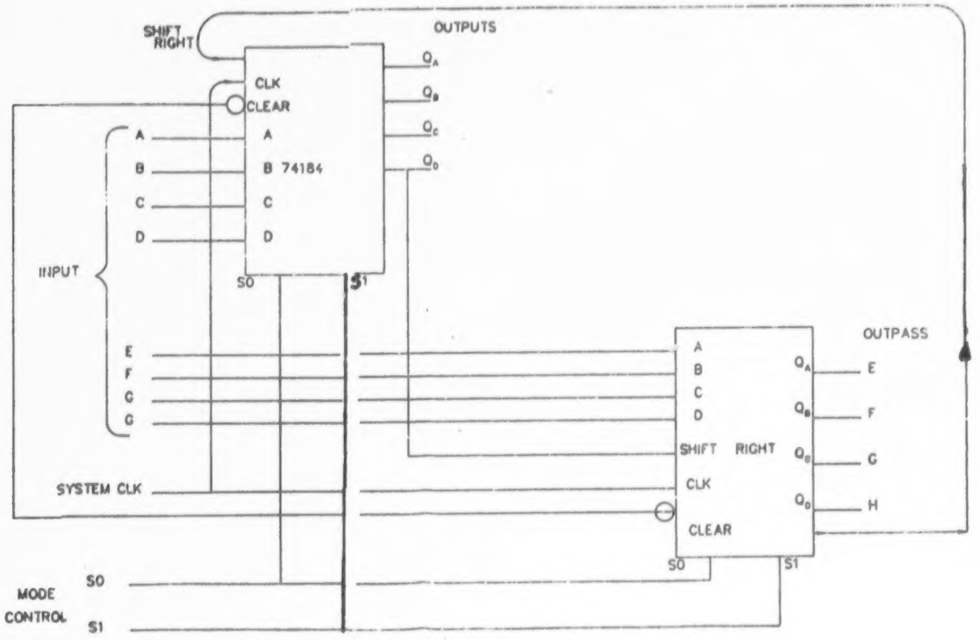
5.


(SHIFT RIGHT INPUT)
CLK
CLEAR
74194
Q_A
Q_B
Q_C
Q_D
S0
S1
1
0


(SHIFT LEFT SERIAL IN)
CLK
CLEAR
74194
Q_A
Q_B
Q_C
Q_D
S0
S1
0
1

ACTIVITY SHEET E 9.2 CONT'D.

6.


SHIFT RIGHT
OUTPUTS
CLK
CLEAR
A
B
C
D
A
B 74184
C
D
Q_A
Q_B
Q_C
Q_D
INPUT
S0
S1
E
F
G
G
SYSTEM CLK
A
B
C
D
SHIFT RIGHT
CLK
CLEAR
Q_A
Q_B
Q_C
Q_D
OUTPASS
E
F
G
H
S0
S1
MODE CONTROL
S0
S1

(parallel load/shift-right recirculating register)

PROGRAM: ELECTRONICS

TASK: SHIFT REGISTERS

TASK #: E 9.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME_______________________ EVALUATION SITE___________

EVALUATOR'S NAME_____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT____________

PERFORMANCE OBJECTIVE:

Analyze, construct, and troubleshoot basic shift register circuit.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out of 7 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 7 points or 80% and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

SHIFT REGISTERS

E 9.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
1.	Was the circuit wired according to the schematic?	Y	N
*2.	Does the circuit function properly?	Y	N
*3.	Was necessary data recorded?	Y	N
4.	Was the correct equipment used?	Y	N
5.	Was the equipment used properly?	Y	N
*6.	Were safety precautions followed?	Y	N
*7.	Was equipment returned to proper storage area?	Y	N

TOTAL POINTS POSSIBLE ___

POINTS NEEDED FOR MASTERY ___

SCORE ___

EXAM E 9.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on shift registers. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D) in the numbered blank space on your ANSWER SHEET. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer 8 out of 10 items correctly, 80%.

EXAM E 9.4 CONT'D.

1. A six-bit serial shift with parallel outputs configured from D flip-flops has been clocked twice with the input low, twice with the input high, and once with the input low. The binary output is what? (shift-right register)

   A. 11000
   B. 011000
   C. 010110
   D. 110010

2. How large a register is needed to store the binary equivalent of 120_{10}.

   A. 8
   B. 5
   C. 6
   D. 7

3. How many clock pulses are required to load 16 bits into two parallel-in parallel-out shift registers. (each register is 8 bits wide)

   A. 1
   B. 16
   C. 2
   D. 4

4. J-K flip-flops cannot be used to construct shift registers.

   A. True
   B. False

5. FIFO would be a characteristic of a serial shift register.

   A. True
   B. False

6. Recirculation prevents data from being lost.

   A. True
   B. False

7. A serial-to-parallel shift register is simply a serial register with the outputs brought out for viewing data.

   A. True
   B. False

EXAM E 9.4 CONT'D.

8. There are three basic types of shift registers.

   A. True
   B. False

9. The mode controls on a universal shift register are used for timing.

   A. True
   B. False

10. Registers can be cascaded to any length.

    A. True
    B. False

EXAM KEY E 9.4 CONT'D

1. B--only five clock pulses leave 0 low from clear
2. C
3. A
4. B
5. A
6. A
7. A
8. B--four
9. B--used to control operational mode
10. A

ELECTRONICS

ANALYZING DIGITAL ELECTRONIC CIRCUITS

E 10: ARITHMETIC CIRCUITS

TASK: Analyze, construct, and troubleshoot basic arithmetic circuits.

PURPOSE: This learning guide will deal with circuits which can add and subtract. All of the addition and subtraction will be done in binary. After completing this learning guide, you should be able to perform binary addition, subtraction, multiplication and division. You will be able to construct simple binary circuits which will perform binary addition, subtraction, multiplication and division. You will be introduced to integrated circuit adders, subtractors, and an arithmetic logic unit (ALU). This learning guide will provide you with important arithmetic concepts, which can be used later in the study of microprocessors.

OBJECTIVE: Given access to all necessary tools and equipment, you will analyze, construct, and troubleshoot basic arithmetic circuits. To master this task you must score 80% on a written exam and performance checklist.

ESTIMATED CLASS TIME: 20 HOURS

ARITHMETIC CIRCUITS

LEARNING STEPS

E 10

READ: Information Sheet E 10.1, "Arithmetic Circuits."

READ: Information on arithmetic circuits in one or more resources listed below.

COMPLETE: Activity sheet E 10.2 on "Arithmetic Circuits."

COMPLETE: Lab performance on arithmetic circuits. Contact your instructor.

COMPLETE: Performance Checklist E 10.3. Contact your instructor.

REVIEW: All material covered by this learning guide

COMPLETE: Written Exam E 10.4. Contact your instructor.

ARITHMETIC CIRCUITS

RESOURCES

E 10

1. CMOS DATA MANUAL (Motorola).
2. Brey, DIGITAL ELECTRONICS (Bobbs-Merrill, 1984).
3. Tokheim, DIGITAL ELECTRONICS TEXT AND ACTIVITY MANUAL (McGraw-Hill, 1984).
4. Tocci, DIGITAL SYSTEMS (Prentice-Hall, 1984).
5. DIGITAL TECHNIQUES STUDENT WORKBOOK (Heath Co., 1981).
6. Williams, DIGITAL TECHNOLOGY (SRA, 1982). 2nd Ed.
7. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Ed.
8. Texas Instrument TTL DATA MANUAL.

INFORMATION SHEET

E 10.1

ARITHMETIC CIRCUITS

To understand digital arithmetic circuits it is best to first understand the binary process for addition, subtraction, multiplication, and division. We will start our investigation of arithmetic circuits with binary addition. Figure E 10.1-1 illustrates the truth table for binary addition. A and B are two binary inputs. "S" equals the sum and "C" represents any carry which might occur. Study the output listed for "S," and note that it is the same output as an exclusive OR gate. Also note the output for "C" with A and B as inputs yields the same output as an NAND gate. Figure E 10.1-2 is the logic diagram for what is called a "half-adder"; this circuit will perform binary addition on two bits of information. The half-adder is the basic circuit for most adders. One of several limitations the half adder exhibits is its inability to handle any previous carry. Figure E 10.1-3 is a circuit which remedies this problem; it is referred to as a "full-adder." The logic expressions for the two outputs are as follows:
$S = A + B + C_{in}$ and $C_{out} = A\ B + C_{in}\ (A + B)$. Develop a truth table for this circuit and you will perform binary addition.

INPUTS		OUTPUTS	
A	B	S	C
0	0	0	0
0	1	1	0
1	0	1	0
1	1	0	1

Figure E 10.1-1

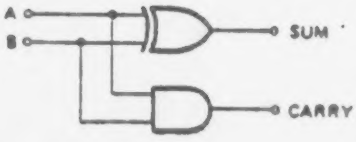


Figure E 10.1-2

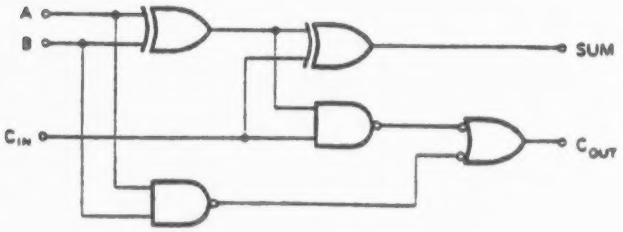


Figure E 10.1-3

Binary subtraction is a little more difficult to perform than binary addition, if you use the standard subtraction process. However, if you use what is referred to as "two's complement," it is as simple as binary addition because you are doing binary addition. Two's complement is the process of changing all ones to zeros, all zeros to ones, and adding a one to the least significant bit. Binary subtraction using two's complement is best illustrated by several examples:

(1) 91_{10} 1011011 1011011
$- 46_{10}$ -0101110 --- Invert 1010001 add 1 -- 1010001
+1
45_{10}
1010010

Add to top number (91_{10})

1011011
+1010010
10101101 = 45_{10}

(2) 77_{10} 1001101
-88_{10} 1011000
---Invert 0100111 1001101
-11 +1 +0101000
0101000 1110101

0001010
+1
1011=-11

Examine these two problems for a better understanding. Take a close look at example two and note the result of the addition. It produced no carry, which is an indication the answer has a negative value. Also note, to put this negative number back into a recognizable form, you must complement and add one.

The preceding example of binary subtraction using two's complement may seem a bit awkward; however, binary gates operating at speeds in the nano-and microsecond range find these manipulations quite easy. You should not be misled by this guide into thinking all subtraction is performed using adders; there are some binary subtraction circuits used. Figure E 10.1-4 is an example of a half-subtractor. Two of these circuits can be configured with an OR gate to make full-subtractor circuit. A larger subtracting circuit can be built, using one half-subtractor and several-full subtractors. Figure E 10.1-5 illustrates a 4-bit parallel subtractor.

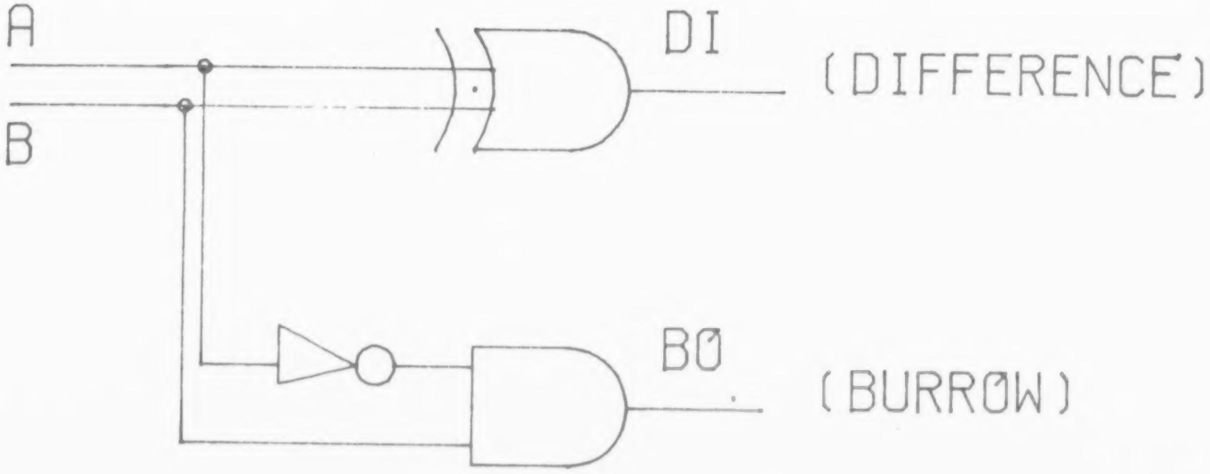


Figure E 10.1-4

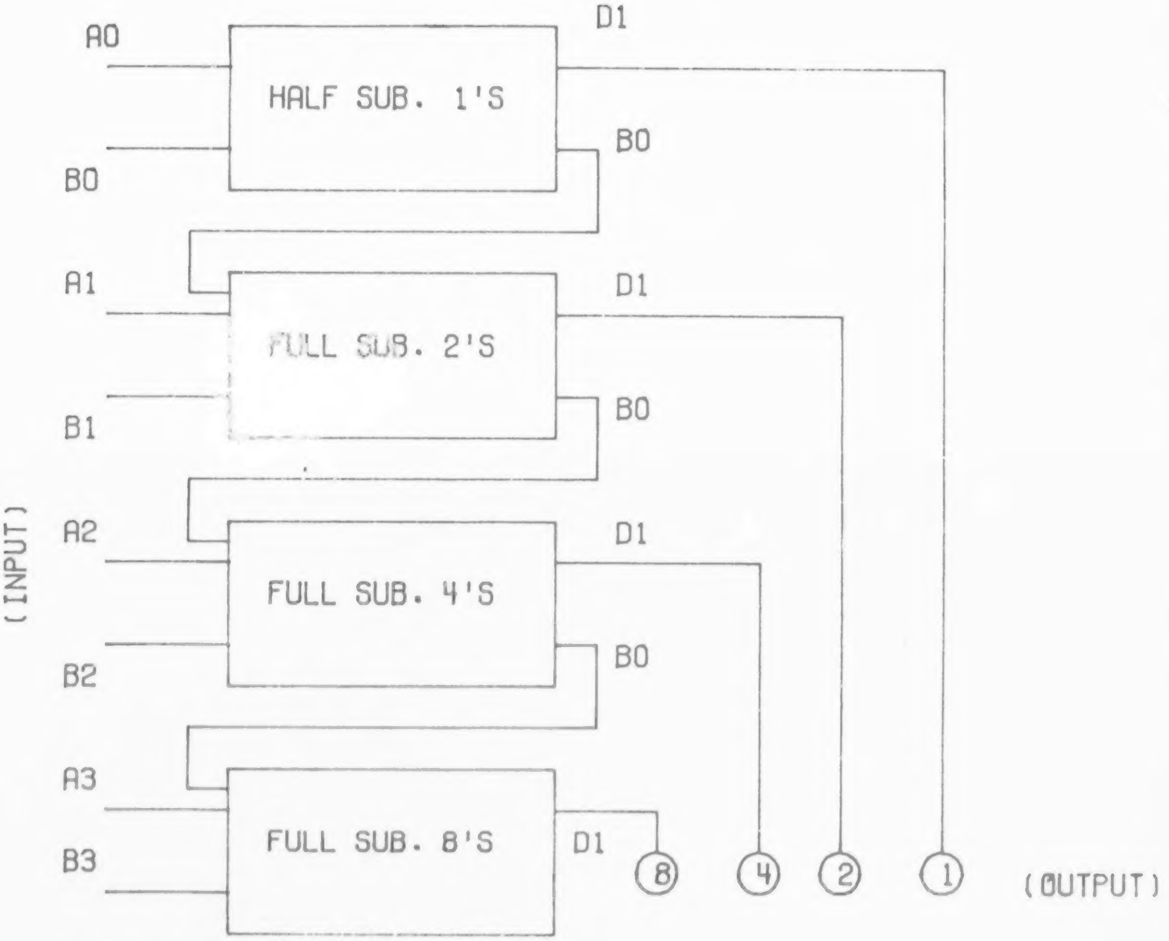

A0
B0
D1
HALF SUB. 1'S
B0
A1
B1
D1
FULL SUB. 2'S
B0
A2
B2
D1
FULL SUB. 4'S
B0
A3
B3
FULL SUB. 8'S
D1
(INPUT)
8
4
2
1
(OUTPUT)

Figure E 10.1-5

Full-adder circuits can easily be used with inverters to do multiple-bit subtraction. Instead of using 2's complement, a system called 1's complement with end-around-carry is used. This system is two's complement, but with a small twist. The end-around-carry is nothing more than the process of adding the 1 bit to the least significant bit. All of the full adders you have seen up to this point have been from discrete gates. There are integrated circuits available for multiple-bit addition, an example in the TTL family is the 7483, a four-bit binary adder.

A 7483 four-bit parallel adder is illustrated by Figure E 10.1-6. You should also note that configuring the circuit to a 4-bit parallel subtractor would be easily accomplished by simply adding the same external gates and inverters. Two input X OR gates could be used as control gates, and this circuit could quickly be made to perform both addition and subtraction. The last point to make about this circuit is that several of these IC's could be used in parallel to perform binary addition or subtraction on 8 or more bits.

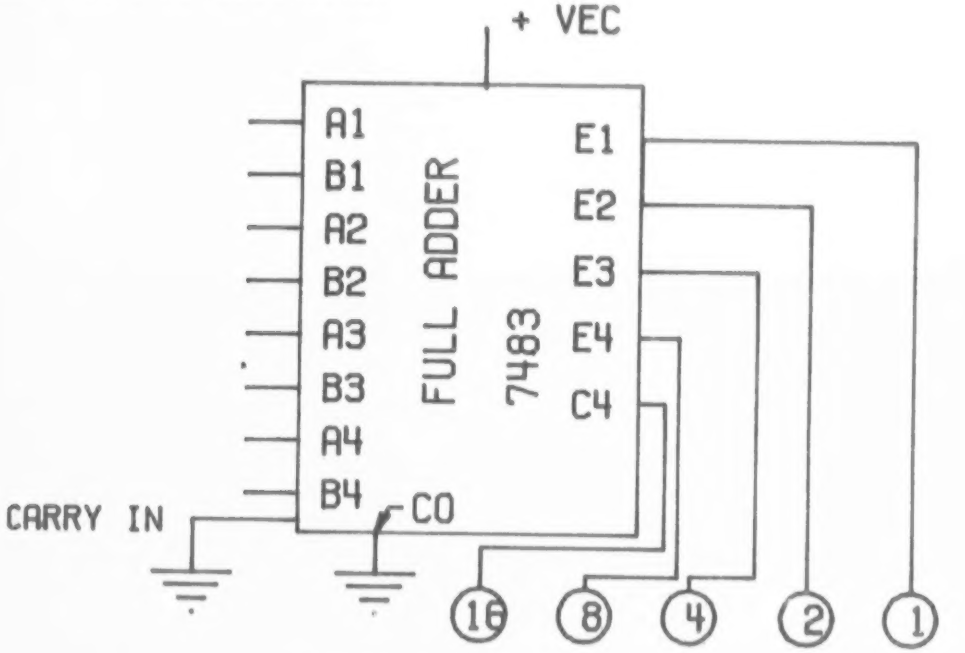


Figure E 10.1-6

Another interesting integrated circuit arithmetic chip is the 74181, ALU. ALU is short for arithmetic logic unit. this device is unique in that it performs logic functions, OR, AND, etc.., and also performs basic arithmetic functions. It can be programmed by four select inputs and a mode input to perform 16 logic operations or 16 arithmetic operations. The device can perform these in either positive or negative logic. To investigate this chip, review its printout in a data manual, breadboard the chip, apply the appropriate logic, and observe its operation.

Binary multiplication is the next arithmetic process we need to look at. Multiplication can be performed by repeated addition. An illustration of this is best shown by example: 10*5 would be accomplished by adding 10, 5 times. Multiplication can thus be handled by binary adders. For large numbers this method would be too slow. To multiply 250 x 4589 would require at least 250 operations.

A faster method used in computers and microprocessors is an add-and-shift algorithm. An algorithm is simply a procedure used to solve a problem. The basic concept behind this algorithm is that for binary multiplication the partial product can only be either the top number exactly if the multiplier digit is a one, or a zero if the multiplier digit is a zero. The process would require two registers for the multiplier and the multiplicand, and a special register initially cleared to zero for the accumulated product. Multiplication would proceed as follows: If a multiplier bit is a one then the multiplicand is added to the accumulator. If the multiplier bit is a zero then zero is added to the accumulator register. The accumulator is then shifted, rotated right one bit position. This procedure would continue until all the multiplier bits have been used. Figure E 10.1-7 is an example of a 4-bit parallel adder using the shift-and-add method of multiplication.

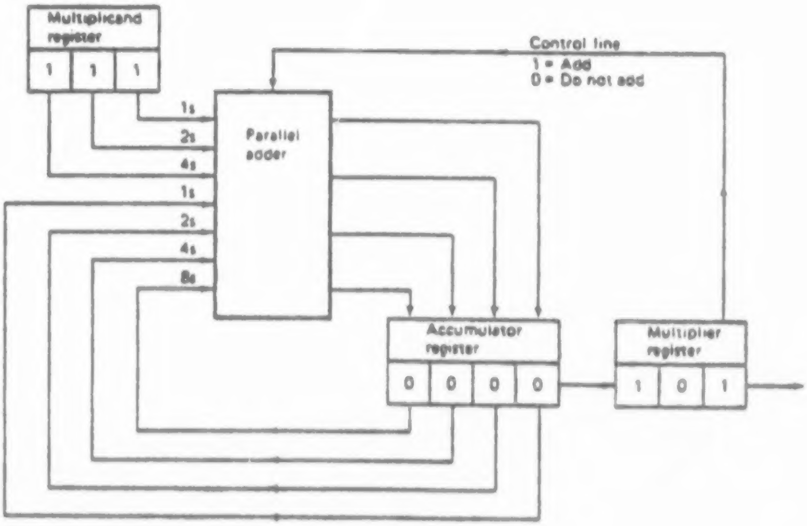


Figure E 10.1-7

Binary division can also be performed in several ways. One method is successive subtraction, which has the divisor subtracted from the dividend and from each successive remainder until a borrow is produced. The quotient is one less than the number of subtractions needed to produce a borrow. This method is like repeated addition; it is fine for small numbers, but too slow for large numbers.

A faster method and one more suited for computers is a subtract-and-shift-left algorithm. The procedure is as follows. The divisor is first subtracted from the most-significant digit of the dividend. If the overflow or carry bit produced by the subtraction is a zero, then the subtraction was possible and a one is written in the quotient register. The result of the subtraction is shifted left one place. The divisor is then subtracted from the shifted result. If a carry bit of 1 is produced, this is an indication the divisor was too large, and a zero would be written in the next digit of the quotient register. The divisor is added back to the result of the subtraction to restore it. The number is shifted left and subtraction is attempted again. When all of the dividend is used, the division is complete. This method is much like the paper and pencil procedure you would use for long division.

This learning guide has only touched on a fraction of the arithmetic circuits used, and has covered only a couple of binary math manipulation techniques. There are numerous circuits and techniques used in binary arithmetic; it would be to your advantage to investigate this topic as completely as possible.

ACTIVITY SHEET

E 10.2

ARITHMETIC CIRCUITS

1. Draw the logic diagram for a half-adder and its truth table.

2. Draw a full-adder circuit (block diagram).

3. Draw the logic diagram for a half-subtractor and its truth table.

4. Draw a full-subtractor circuit (block diagram).

5. Draw a circuit diagram of a 4-bit subtractor, using inverters and full-adders to perform subtraction by 1's complement with end-around-carry.

6. Draw a circuit diagram for a 4-bit full-adder using a 7483.

7. A 74181 ALU provides __________ arithmetic operations.

8. The 74181 ALU provides _________ logic operations.

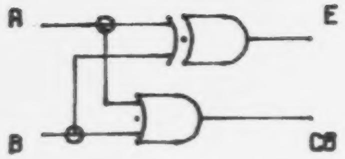
9. Can you perform 4-bit multiplication using the 74181 ALU?

10. Will the 74181 perform both positive and negative logic?

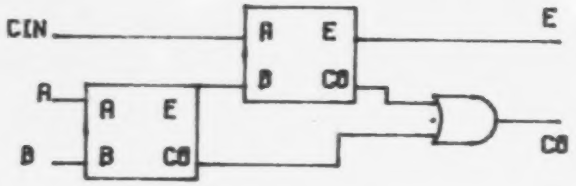
ACTIVITY SHEET E 10.2

ANSWER SHEET

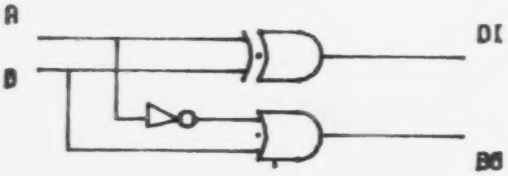
1.



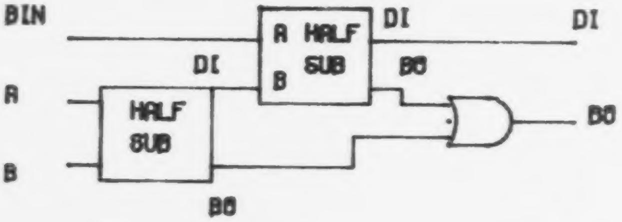
2.


CIN
A
B
A
E
B
CO
A
E
B
CO
E
CO

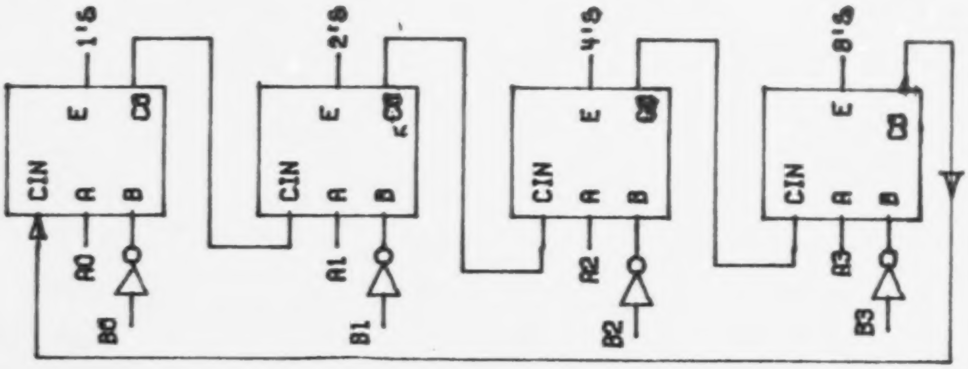
3.



4.


BIN
A
B
HALF SUB
DI
A
B
HALF SUB
DI
BO
DI
BO
BO

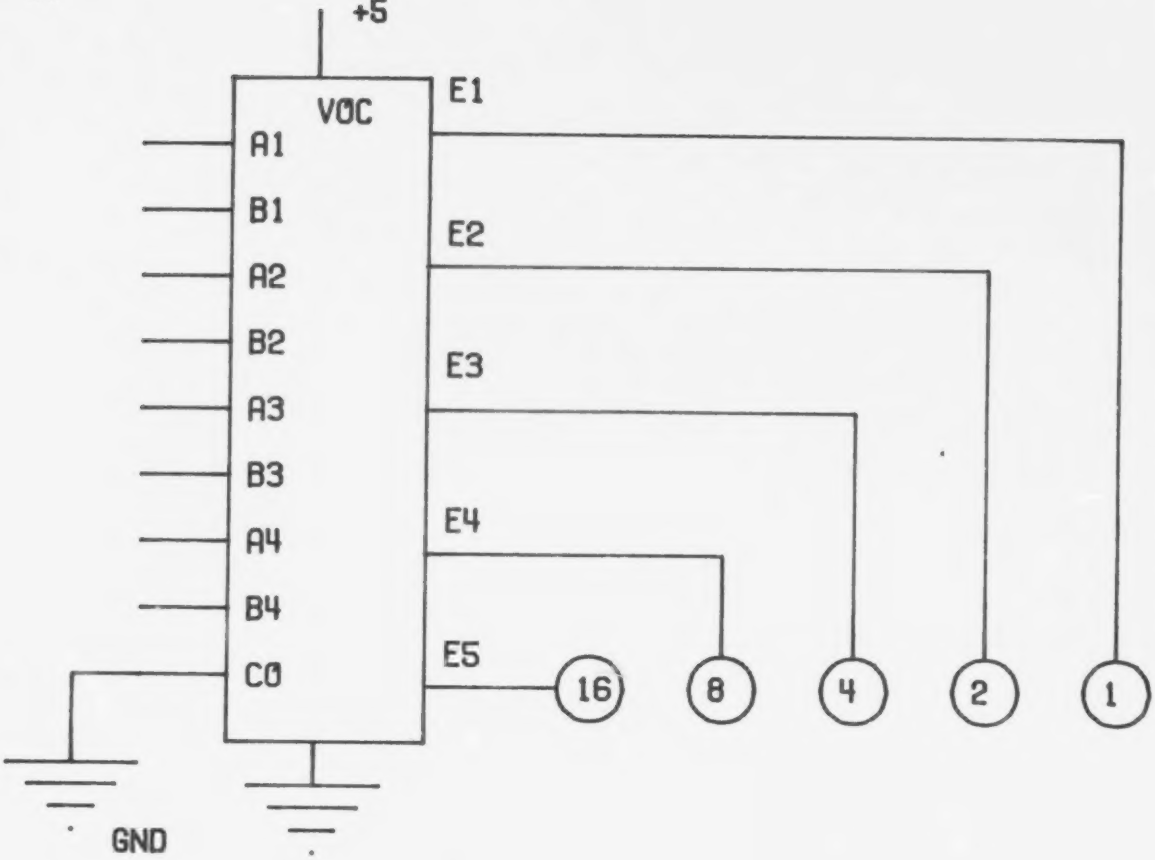
5.


1'S
E
CO
CIN
A
B
A0
B0
2'S
E
CO
CIN
A
B
A1
B1
4'S
E
CO
CIN
A
B
A2
B2
8'S
E
CO
CIN
A
B
A3
B3

ACTIVITY SHEET E 10.2

ANSWER SHEET

6.


+5
VOC
E1
A1
B1
E2
A2
B2
E3
A3
B3
E4
A4
B4
E5
C0
16
8
4
2
1
GND

7. 16

8. 16

9. Yes

10. Yes

PROGRAM: ELECTRONICS

TASK: ARITHMETIC CIRCUITS

TASK #: E 10.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ____________

TERMINAL PERFORMANCE OBJECTIVE:

Analyze, construct, and troubleshoot basic arithmetic circuits.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

ARITHMETIC CIRCUITS

E 10.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED OR CHECKED	RATING YES/NO	
1.	Was the circuit wired according to the schematic?	Y	N
*2.	Does the circuit function properly?	Y	N
*3.	Was necessary data recorded?	Y	N
4.	Was the correct equipment used?	Y	N
5.	Was the equipment used properly?	Y	N
*6.	Were safety precautions followed?	Y	N
*7.	Was equipment returned to proper storage area?	Y	N

TOTAL POINTS POSSIBLE ___

POINTS NEEDED FOR MASTERY ___

SCORE ___

EXAM E 10.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Arithmetic Circuits. Each of the questions or incomplete statements is true or false. Place the letter associated with that choice (A or B) in the numbered blank space on your ANSWER SHEET. DO NOT WRITE ON THIS TEST!! To master this exam you must answer 8 out of 10 items correctly, 80%.

EXAM E 10.4

1. 010010 is two's complement of 101110.

   A. True
   B. False

2. All binary subtraction is performed using one's or two's complement.

   A. True
   B. False

3. The only difference between a half-adder and a half-subtractor is an inverter.

   A. True
   B. False

4. Subtraction can be performed using adders.

   A. True
   B. False

5. One's complement and two's complement are basically the same thing.

   A. True
   B. False

6. Addition and subtraction cannot be performed by the same circuit.

   A. True
   B. False

7. Multiplication can be performed by an add-and-shift-left algorithm.

   A. True
   B. False

8. A 74183 is a 4-bit integrated circuit adder.

   A. True
   B. False

9. Division can be accomplished by a subtract-and-shift-left algorithm.

   A. True
   B. False

10. The 74181 ALU chip will do both arithmetic and logic operations.

    A. True
    B. False

EXAM KEY E 10.4

1. A
2. B
3. A
4. A
5. A
6. B
7. B
8. B
9. A
10. A

ELECTRONICS

ANALYZING DIGITAL ELECTRONIC CIRCUITS

E 11: LOGIC SYSTEMS

TASK: Analyze, construct, and troubleshoot basic digital logic systems and circuits.

PURPOSE: After having completed the last ten digital tasks, you should have a good understanding of basic logic circuits. Also, you should begin to understand how these basic logic circuits can be configured to form logic systems. Examples of digital systems you are already familiar with are frequency counters, calculators, and digital clocks. This learning guide will introduce you to some of the fundamental concepts of troubleshooting digital circuits and systems. After completing this guide you should be able to troubleshoot simple basic logic circuits and systems.

OBJECTIVE: Given access to all necessary tools, equipment and schematic diagrams, you will analyze, construct and troubleshoot basic logic circuits and systems. To master this task you must score 80% on a written exam and performance checklist.

ESTIMATED CLASS TIME: 25 HOURS

LOGIC SYSTEMS

LEARNING STEPS

E 11

READ: Information Sheet E 11.1, "Digital Troubleshooting."

READ: Information on digital troubleshooting in one or more resources listed below.

COMPLETE: Activity Sheet E 11.2 on "Digital Troubleshooting."

COMPLETE: Lab performance on digital troubleshooting. Contact your instructor.

REVIEW: All materials covered by this learning guide.

COMPLETE: Performance Checklist E 11.3. Contact your instructor.

COMPLETE: Written exam E 11.4. Contact your instructor.

LOGIC SYSTEMS

RESOURCES

E 11

1. CMOS DATA MANUAL (Motorola).
2. Brey, DIGITAL ELECTRONICS (Bobbs-Merrill, 1984).
3. Tokheim, DIGITAL ELECTRONICS TEXT AND ACTIVITY MANUAL (McGraw-Hill, 1984).
4. Tocci, DIGITAL SYSTEMS (Prentice-Hall, 1984).
5. DIGITAL TECHNIQUES STUDENT WORKBOOK (Heath Co., 1981).
6. Williams, DIGITAL TECHNOLOGY (SRA, 1982). 2nd Ed.
7. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Ed.
8. Texas Instrument TTL DATA MANUAL.

INFORMATION SHEET

E 11.1

DIGITAL TROUBLESHOOTING

The key ingredients involved in good troubleshooting include attitude, skill, and equipment. This learning guide will attempt to cover some of the concepts of troubleshooting by discussing some specific points under each heading.

ATTITUDE:

When a digital circuit or system is not working properly, there is usually a logical reason for the malfunction. It is the job of the electronics technician to find the problem and fix it. This will require a systematic logical approach to solving the problem. As a technician you will need to develop a logical pattern for troubleshooting the circuit. Have your work area clean and with plenty of room for the circuits and equipment. Keep technical manuals, logic diagrams, schematic diagrams, and functional diagrams handy. Store equipment and test leads nearby, but not in the way.

Many circuit problems will be easy to diagnose and fix; however, there will be some which will be stubborn and very difficult to solve. As an electronics technician you need to develop patience, and be able to stick with the problem until you have solved it. If you can develop the attitude that you are going to beat the problem and not let it beat you, then you will have made a positive step towards developing an attitude which will allow you to solve the difficult problems involved in troubleshooting.

SKILL:

Skill in troubleshooting may be better defined as a good grasp of technical knowledge. All of the reading and circuit study you have done up to this point provides you with a foundation of technical knowledge about the circuit you are troubleshooting. It is this knowledge which allows you to understand how the circuit is to function, and what might be causing it to not function in its prescribed manner. Without this knowledge the technician would be unable to even begin troubleshooting. If you are unfamiliar with a piece of equipment or a circuit, take some time and read the service data for the circuit; in the long run, this will save you time.

EQUIPMENT:

There are several pieces of equipment which can be used in digital troubleshooting; some of it is essential. A digital multimeter is probably the most essential piece of equipment. It will allow you to measure voltage, check current, measure resistance and run continuity checks. Many problems can be tracked back to the power supply, and a quick check with a digital multimeter will tell you if you have the proper voltage to the circuits.

A logic clip, fastened over the integrated circuit, allows easy connection of test equipment to the I.C. Logic clips can be purchased in a variety of sizes: 16, 24, 28, and 40 pin lengths. The logic clip is not an essential piece of equipment; but its price is low, and it does aid in chip voltage measurements. Some logic clips are more than clips which bridge the pin connections up off of the circuit board; they have built-in circuitry which allows the user to view the logic at each pin.

The logic probe could probably be classified as an essential piece of equipment. It allows the user to "probe," or see, the logic at the probe's tip. Most probes will display a logic low, a logic high, or a train of logic pulses. The probe might display lamp off: logic low, lamp on (bright): logic high, lamp dim: floating output or bright output, and lamp flashing: pulsing logic.

A logic pulser is another piece of essential equipment, often used in conjunction with a logic probe. The pulser allows the user to inject ones or zeros into the circuit. Check Figure E 11.1-1.

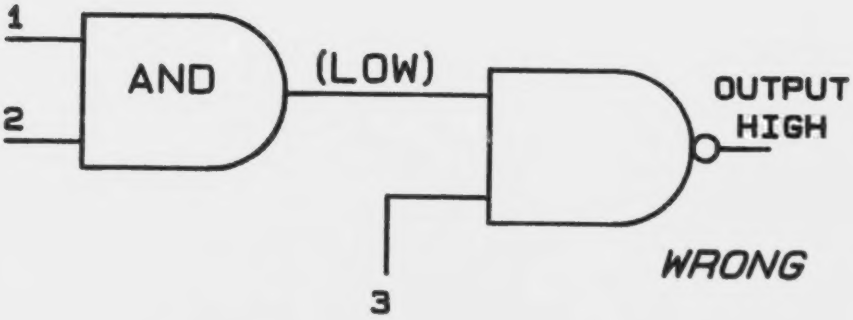


Figure E 11.1-1

The output of the NAND gate which remains high. Using a logic probe to test inputs 1, 2, and 3, you find them all high. You very quickly can deduce that something is wrong. Using a probe on the output of the AND gate, you discover its output is low. The question is "which chip is at fault?" Place the logic probe and pulser like that of Figure E 11.1-2.

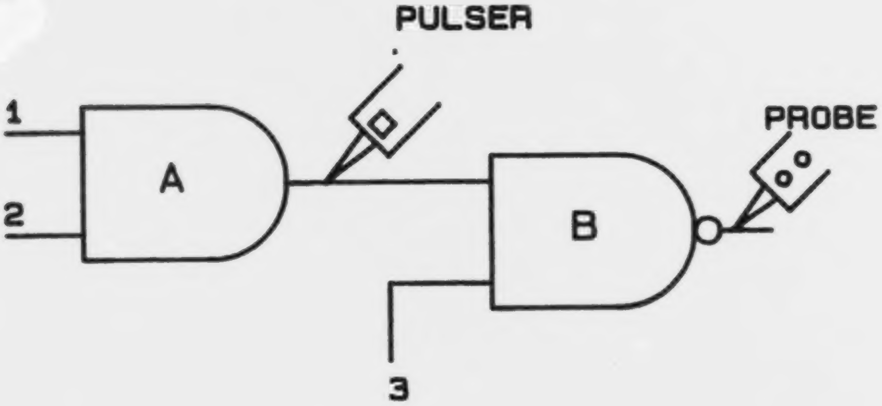


Figure E 11.1-2

With the probe in place, pulse the input to the NAND. The probe should blink, indicating a change at the NAND. If it doesn't change, the NAND gate is bad. However, what if the low on the output of the AND was caused by a shorted output to ground? To check this, place the probe and pulser as in Figure E 11.1-3 and pulse the line.

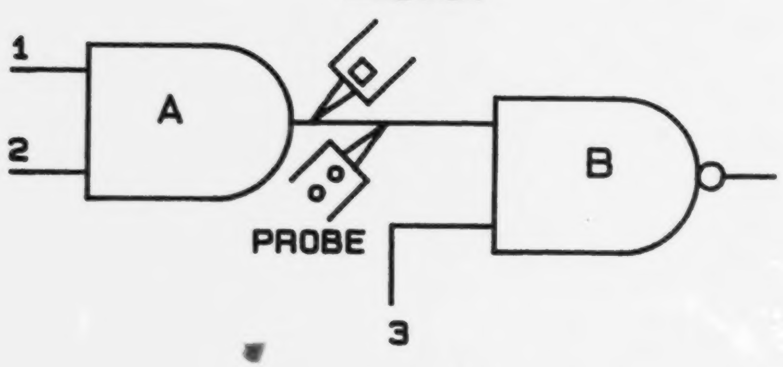


Figure E 11.1-3

If the probe blinks, the NAND is bad; its input changed state, so its output should have changed states also. If the probe doesn't blink, you know the line is shorted to ground. You can determine which chip is shorted by touching the case; if it is hot, that indicates a short and excessive current.

For a more detailed explanation of the operation and use of logic pulsers and probes, check the operation manual for the equipment you are using. There are also numerous books on using probes and pulsers to do digital troubleshooting.

A fifth handy troubleshooting aid is the current tracer probe. This device lets you locate shorts on the circuit card or mother board. A current tracer senses the magnetic field produced by the flow of current in the circuit. The logic pulser can be used to generate a pulsing signal which will make the current tracer blink, indicating current flow. If you set the tip of the tracer on a printed circuit trace and slide the tracer along the foil, an LED in the tip of the tracer will pulse as long as there is current. When you slide past a point which is shorted, the lamp will glow dim or go out. This piece of equipment is not essential, but it does make locating shorts an easier task.

Integrated circuit testers are pieces of equipment which would be nice to have, but too costly to justify. These pieces of equipment would be used by large firms dealing in a volume business of logic troubleshooting.

The oscilloscope, or scope, has been an essential piece of test equipment for years. An oscilloscope is an electronic display device that "draws" a graph of signal voltage amplitude compared to time or frequency on a CRT screen.

A shape is used to analyze the quality and characteristic of an electronic signal, using a probe that touches a test point in the circuit.

A companion to the scope, the logic analyzer, is a multichannel oscilloscope with memory. It captures and stores a number of digital signals, letting you view them simultaneously. If each signal is a bit on the data bus, you can see the entire data byte at one time.

A logic analyzer is an expensive piece of equipment. It is not essential for troubleshooting. It can be a valuable tool for the software or hardware designer, but for the small business computer user who wants to fix his/her own equipment, the logic analyzer is expensive overkill.

There are other pieces of specialized troubleshooting equipment which this learning guide has not covered. Most of the specialized equipment is very expensive and could be put in the category of "nice to have" but not essential. The point to remember when considering equipment is to know how to use what you have. Take time to read the operation and instruction manual for each piece of equipment. It will be well worth it in your troubleshooting experiences.

Developing the technical skill, acquiring the proper equipment and attitudes, will go a long way in making you a good troubleshooter; however, there can be no substitute for experience. Experience will teach you many troubleshooting techniques. This learning guide will conclude by outlining some basic digital troubleshooting techniques:

USE YOUR SENSES

Look, smell and feel. Sometimes failed components became discolored or develop bubbles or colored spots. Distinctive smells. Shorted chips will become very warm. By using your finger you will be able to find shorted IC'S.

APPLY HEAT, COOL IT

Heating and then cooling is a fast technique for locating the cause of intermittent problems. Frequently as an aging device warms up under normal operation, it becomes marginal and then intermittently quits working. If you heat the area where a suspected bad chip is located until the intermittent failures begins, then methodically cool each device with a short blast of canned coolant, you can quickly cause a marginally defective chip to function again. By alternately heating, cooling, heating, and cooling, you can pinpoint the trouble in short order.

PIGGYBACKING

Figure E 11.1-4 illustrates yet another way you can chase down intermittents caused by a break in a chip bond, or wire, inside the chip housing that allows good contact only when the chip is cool. Place a good chip over the top of a suspected chip and energize the circuit. You may need to squeeze in the pins of the good chip slightly so they make good contact with the pins of the suspected device. If the intermittent failure is caused by an open connection, the new chip will react to input data and cause its output to act accordingly.

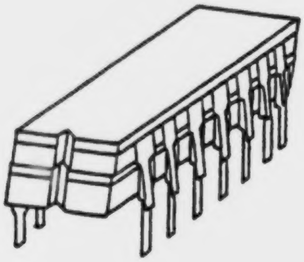


Figure E 11.1-4

CHIP SUBSTITUTION

Substitution of chips is an easy way of finding a faulty device, provided the chips are in your stock and the chips you desire to substitute are in sockets. If the chip is not in a socket you will have to very carefully desolder it from the board; don't attempt this unless you have had some experience at desoldering. If you decide to desolder the chip, replace it with a good quality socket.

Troubleshooting involves skill, proper equipment, the right attitude and experience. As a student of electronics, you are learning the necessary skills and how to use the troubleshooting equipment, also you should be developing the proper attitudes and gaining as much experience as possible. Take every opportunity available to troubleshoot malfunctioning electronics equipment. Keep a log of your repairs. Before you are aware of it, you will develop the skills required to do digital troubleshooting.

ACTIVITY SHEET

E 11.2

DIGITAL TROUBLESHOOTING

Questions 1-3 use Figures E 11.2-1, E 11.2-2, and E 11.2-3. Figure E 11.2-1 is a functional block diagram of a frequency counter; Figure E 11.2-2, a schematic diagram for a frequency counter; and Figure E 11.2-3, a troubleshooting flowchart for a frequency generator. Look these diagrams and schematics over to familiarize yourself with the operation and circuitry for this frequency counter. Use these diagrams to solve the problems listed below.

1. What might be the problem if the middle digit lights, but with the wrong data, (Use diagrams to list possible problems.) and you have determined that all I.C.'s are working.

2. Next, the counter will not reset; it merely keeps counting.

3. Assume there is no counter output. (No output from 7400)

Fill in the blanks for these questions.

4. Service or diagnostic hints are often given in the equipment ___________________.

5. You can use a ____________________ to guide you to the problem in the least number of steps.

6. Sometimes a problem can be isolated by ___________________ two identical circuit components.

7. On a logic diagram, a bar over a signal means the line is low when the signal is ______________________.

8. Normally, IC chips feel hot to the touch (True/False).______

ACTIVITY SHEET E 11.2 CONT'D.

9. Replacing all the IC's in the suspected area may be effective, if the IC's are mounted in ____________________.

10. TTL logic reacts to an open input as if it were a __________ (high/low) logic level.

11. Logic probes are most useful for finding _____________ logic faults.

12. If the system malfunctions only momentarily during operation, it is called a __________________ failure.

13. An oscilloscope is used for finding the ____________________ relationship between several signals.

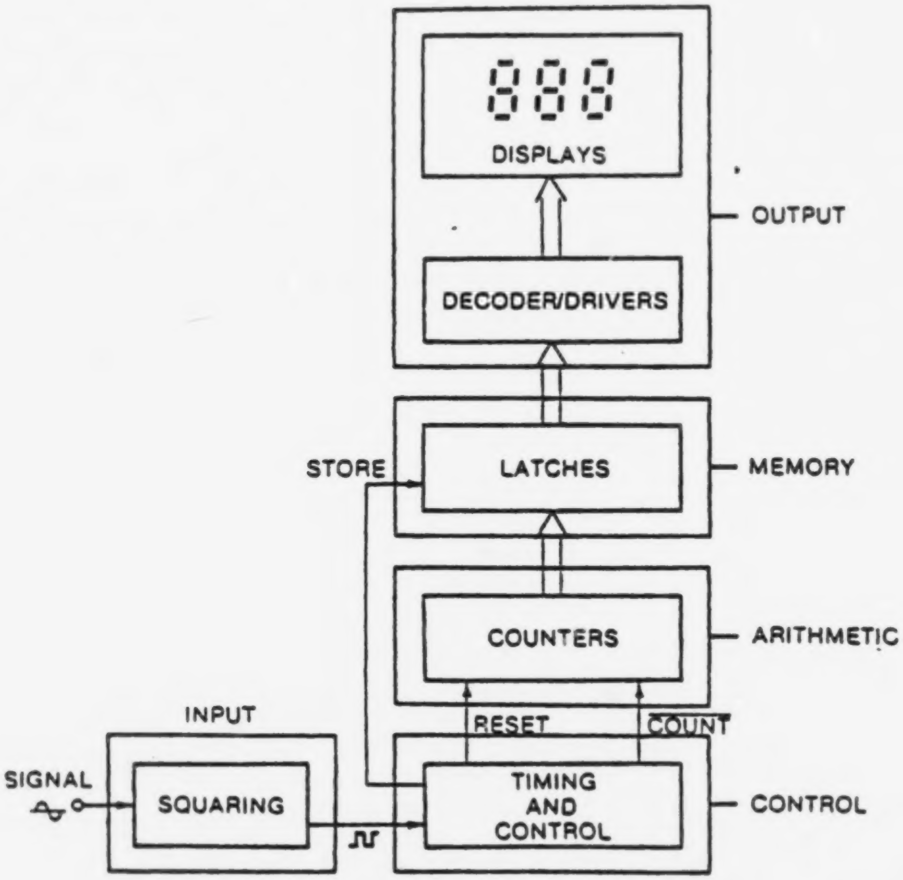

888
DISPLAYS
OUTPUT
DECODER/DRIVERS
STORE
LATCHES
MEMORY
COUNTERS
ARITHMETIC
INPUT
RESET
COUNT
SIGNAL
SQUARING
TIMING AND CONTROL
CONTROL

Figure E 11.2-1

NOTE: The diagram is used to show the individual logic circuits, drawn in block form, connected together to form the digital system, i.e., the frequency counter. This type of diagram aids the technician in understanding circuit configuration, signal processing, and system function.

ACTIVITY SHEET E 11.2 CONT'D.

MSI frequency counter.

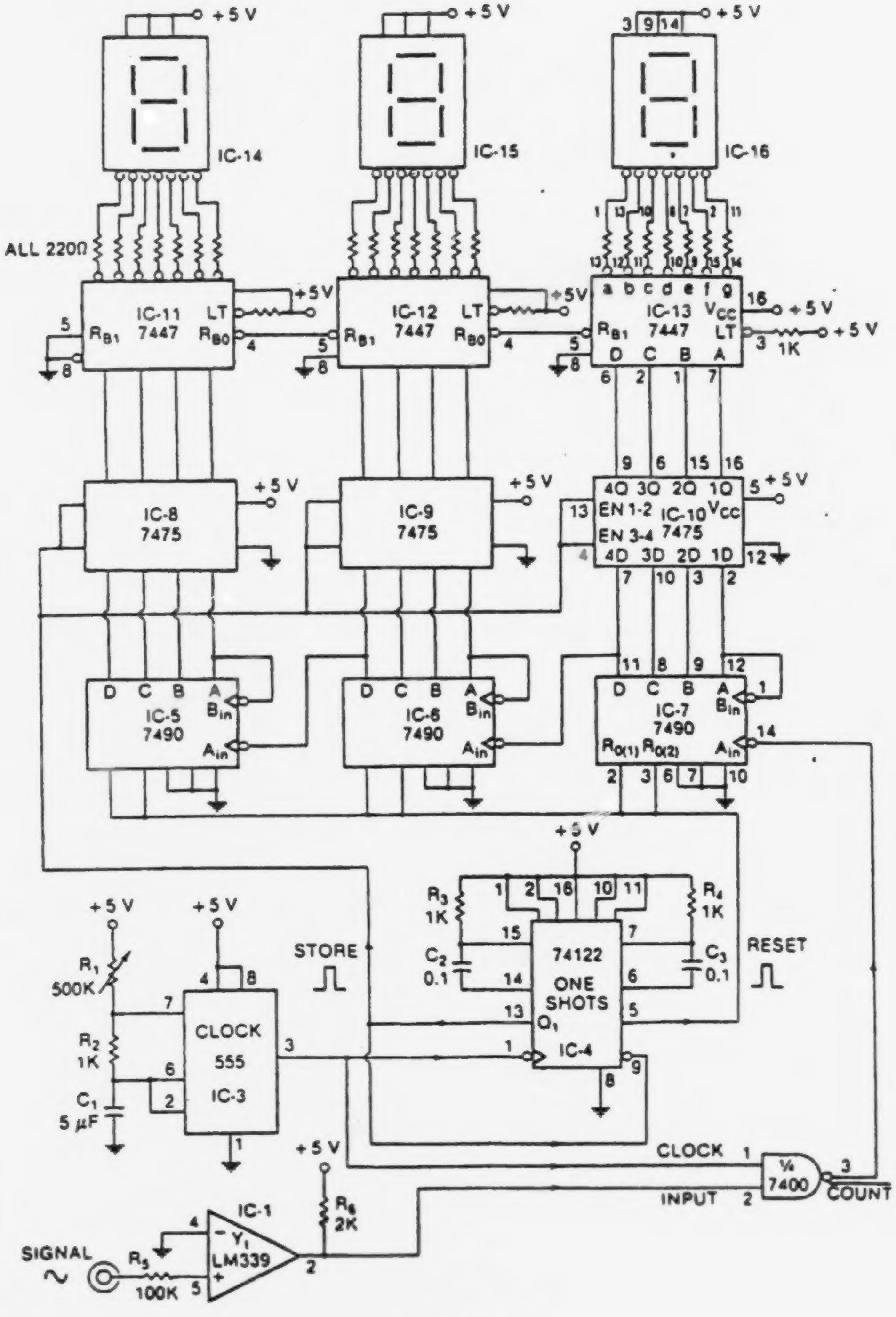

+5 V
IC-14
IC-15
IC-16
ALL 220Ω
IC-11
7447
IC-12
7447
IC-13
7447
LT
R_{B1}
R_{B0}
a b c d e f g
V_{CC}
1K
IC-8
7475
IC-9
7475
IC-10
7475
4Q 3Q 2Q 1Q
EN 1-2
EN 3-4
4D 3D 2D 1D
IC-5
7490
IC-6
7490
IC-7
7490
D C B A
B_{in}
A_{in}
$R_{0(1)}$ $R_{0(2)}$
R_3 1K
R_4 1K
C_2 0.1
C_3 0.1
74122
ONE SHOTS
IC-4
Q_1
STORE
RESET
R_1 500K
R_2 1K
C_1 5 μF
CLOCK
555
IC-3
CLOCK
INPUT
¼ 7400
COUNT
IC-1
Y_1
LM339
R_6 2K
SIGNAL
R_5 100K

Figure E 11.2-2

ACTIVITY SHEET E 11.2 CONT'D.

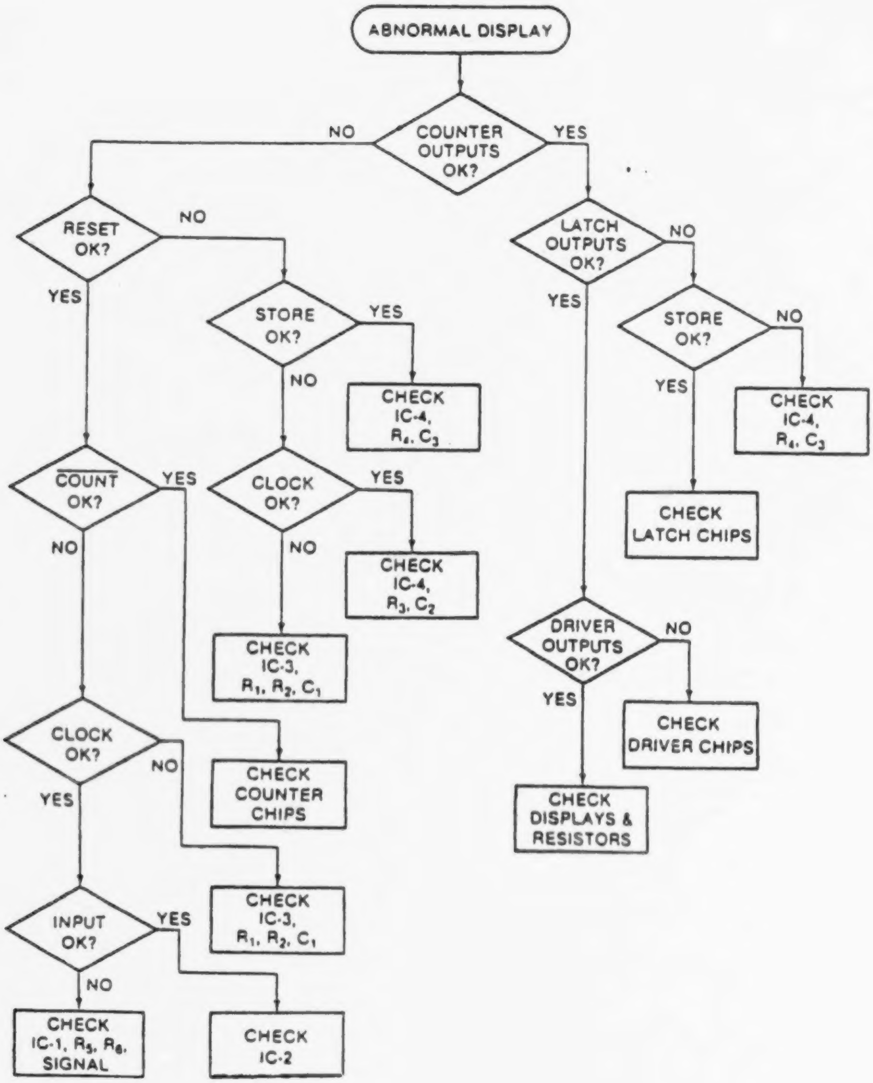

ABNORMAL DISPLAY
COUNTER OUTPUTS OK?
NO
YES
RESET OK?
NO
YES
STORE OK?
YES
NO
CHECK IC-4, R4, C3
COUNT OK?
YES
NO
CLOCK OK?
YES
NO
CHECK IC-4, R3, C2
CHECK IC-3, R1, R2, C1
CLOCK OK?
YES
NO
CHECK COUNTER CHIPS
CHECK IC-3, R1, R2, C1
INPUT OK?
YES
NO
CHECK IC-1, R5, R6, SIGNAL
CHECK IC-2
LATCH OUTPUTS OK?
NO
YES
STORE OK?
NO
YES
CHECK IC-4, R4, C3
CHECK LATCH CHIPS
DRIVER OUTPUTS OK?
NO
YES
CHECK DRIVER CHIPS
CHECK DISPLAYS & RESISTORS

Figure E 11.2-3 (Troubleshooting Flowchart)

NOTE: This is a troubleshooting flowchart used to aid the technician in a logical procedure for tracing circuit problems.

ACTIVITY SHEET E 11.2

ANSWER SHEET

ANSWERS:

1. Using the flowchart, start at the beginning and work towards solution. The counter outputs ck. of, and the latcher also appear to be working. This leads you to the driver outputs. If they check ok, then your problem is in a resistor or the display itself. If the driver output is wrong, then the driver chip should be checked and substituted.

2. Review of the functional block diagram (Figure E 11.2-1) and the schematic (Figure E 11.2-2) shows you that the 74122 provides a reset pulse to the latcher and the counters. Using the flowchart, you will determine that the counters are not giving the proper output, so you will move the reset on block. It is obvious that the reset is not ok, so you will need to check the store function. If the store (latches) are working properly, you will be led to the reset section, IC4. A check of this area should solve the problem.

3. Reset checks ok, so you must move to count. At this point, a scope check indicate, there is no output from the NAND gate. You would next move the clock check, where a check by the scope shows a good clock signal. From here you would move to the input check block, which shows no input to the 7400 NAND gate. This leaves you with but one area, the amp. A check around this area yields a broken input from the BNC input connecter.

4. Manual
5. Flowchart
6. Substituting
7. Active (true)
8. False
9. Sockets
10. High
11. Static
12. Intermittent
13. Time

PROGRAM: ELECTRONICS

TASK: LOGIC SYSTEMS

TASK #: E 11.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ________________ EVALUATION SITE ______________

EVALUATOR'S NAME ________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ______________

TERMINAL PERFORMANCE OBJECTIVE:

Analyze, construct, and troubleshoot basic digital logic systems and circuits.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 and must score at least 6 out of 7 points or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 7 points or 80% and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

LOGIC SYSTEMS

E 11.4

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the circuit wired according to the schematic?	Y N
*2.	Does the circuit function properly?	Y N
*3.	Was necessary data recorded?	Y N
4.	Was the correct equipment used?	Y N
5.	Was the equipment used properly?	Y N
*6.	Were safety precautions followed?	Y N
*7.	Was equipment returned to proper storage area?	Y N

TOTAL POINTS POSSIBLE ___

POINTS NEEDED FOR MASTERY ___

SCORE ___

EXAM E 11.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on Digital Troubleshooting. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer 8 out of 10 items correctly, 80%.

EXAM E 11.4 CONT'D.

1. The first step in digital logic troubleshooting is to ______.

   A. connect your test equipment
   B. replace all bad components
   C. isolate the faulty subsystem
   D. gather technical information

2. The method used to isolate a faulty system in a digital system depends on __________.

   A. available information
   B. ease of parts replacement
   C. system's diagnostic capability
   D. all of the above

3. What should you consult first to find the location of an IC on a PC board?

   A. repair log
   B. PC board layout drawing
   C. troubleshooting flowchart
   D. parts list

4. What symbol is used to indicate signal line danger on a timing waveform diagram?

   A. bubble
   B. dot
   C. bar
   D. arrow

5. How many inputs can a logic analyzer display simultaneously?

   A. 1 to 2
   B. 2 to 4
   C. 6 to 7
   D. 8 to 16 or more

6. An open TTL logic input reads approximately __________.

   A. -2V
   B. 0V
   C. +2V
   D. -5V

7. A marginal logic level is best found with a/an __________.

   A. logic probe
   B. oscilloscope
   C. logic analyzer
   D. test clip

8. A logic probe is useful for __________.

   A. checking a clock line
   B. checking the time relationship between logic signals
   C. monitoring waveform rise times
   D. finding marginal voltage levels

9. What instrument uses LED's to indicate logic level states?

   A. logic probe
   B. oscilloscope
   C. voltmeter
   D. logic analyzer

10. What instrument is best to use for finding a circuit board short circuit?

   A. scope
   B. DVM
   C. logic probe
   D. current tracer

EXAM KEY E 11.4

1. D
2. D
3. D
4. D
5. D
6. C
7. B
8. A
9. A
10. D

ELECTRONICS

ANALYZING DIGITAL ELECTRONIC CIRCUITS

E 12: MEMORY CIRCUITS

TASK: Analyze, construct, and troubleshoot memory circuits.

PURPOSE: This learning guide will introduce some of the more common integrated circuit types of memory, RAM, ROM, PROM, EPROM, ETC. They will be defined, and examples of each will be given. Memory is a vast topic in electronics, and only a very small portion of it will be covered by this guide. It will be up to you to investigate this topic in a much greater detail according to your memory requirements and needs.

OBJECTIVE: Given access to all necessary tools and equipment, you will analyze, construct, and troubleshoot memory circuits. To master this task, you must score 80% on a written exam and performance checklist.

ESTIMATED TIME: 12 HOURS

MEMORY CIRCUITS

LEARNING STEPS

E 12

READ: Information Sheet E 12.1, "Memory."

READ: Information on memory devices in one or more of the resources listed below.

COMPLETE: Activity Sheet, E 12.2 on "Memory."

COMPLETE: Lab performance on memory. Contact your instructor.

REVIEW: All material covered by this learning guide.

COMPLETE: Performance Checklist E 12.3. Contact your instructor.

COMPLETE: Written Exam E 12.4. Contact your instructor.

MEMORY CIRCUITS

RESOURCES

E 12

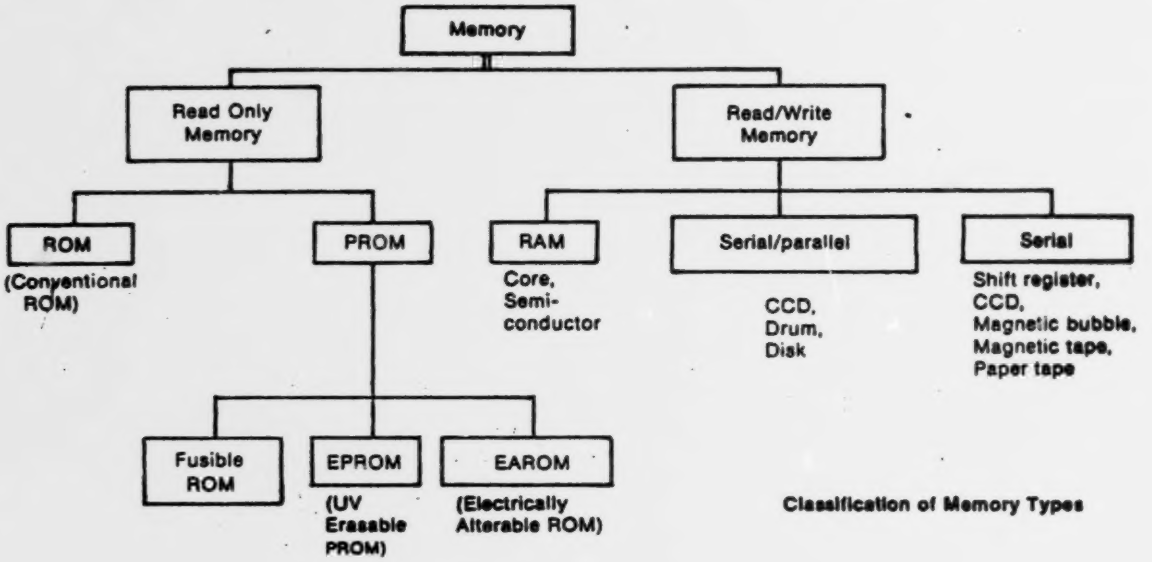
1. CMOS DATA MANUAL (Motorola).
2. Brey, DIGITAL ELECTRONICS (Bobbs-Merrill, 1984).
3. Tokheim, DIGITAL ELECTRONICS TEXT AND ACTIVITY MANUAL (McGraw-Hill, 1984).
4. Tocci, DIGITAL SYSTEMS (Prentice-Hall, 1984).
5. DIGITAL TECHNIQUES STUDENT WORKBOOK (Heath Co., 1981).
6. Williams, DIGITAL TECHNOLOGY (SRA, 1982). 2nd Ed.
7. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Ed.
8. Texas Instrument TTL DATA MANUAL.

INFORMATION SHEET

E 12.1

MEMORY

The term memory may be broadly divided into two major categories: read-only memory (ROM) and read/write memory. Read/write memory allows information to be easily written into or read out of any of its elements; read-only memory acts as a permanent or semipermanent storehouse of information. A block diagram of the classification of memory types is shown below.


Memory
Read Only Memory
Read/Write Memory
ROM
(Conventional ROM)
PROM
RAM
Core, Semi-conductor
Serial/parallel
CCD, Drum, Disk
Serial
Shift register, CCD, Magnetic bubble, Magnetic tape, Paper tape
Fusible ROM
EPROM
(UV Erasable PROM)
EAROM
(Electrically Alterable ROM)

Classification of Memory Types

Figure E 12.1-1

Memory is also sometimes divided into prime memory and secondary memory. Secondary memory would be thought of as backup memory: floppy disk, hard disk, tape, or today, compact disk. This learning guide will be concerned only with prime memory.

Before we start with this topic some definition of terms may be in order:

READ-ONLY MEMORY: (ROM) A type of memory which can only be read from and not written to. There are several different types of read only memory.

READ/WRITE MEMORY: This type of memory can be read from or written to. It is sometimes called RAM.

ROM: A type of read-only memory, which is "mask programmed" at the factory. This type of memory is used where high volume is the concern.

PROM: Programmable read-only memory. This type of memory is a permanent type of memory usually programmed in the field for limited production applications.

EPROM: Erasable Read-Only Memory. A type of nonvolatile memory which is semi-permanent; that is, it can be altered but not easily. It is erasable by using ultraviolet light.

SRAM: Static random-access memory. This is a type of volatile (loss when power is removed) memory. It is called random-access because any cell can be accessed at any time.

DRAM: Dynamic random-access memory. A type of read/write memory; however, unlike static RAM the contents of dynamic will be lost if not constantly updated.

Prime memory is the type of memory which is used while the digital system is working or performing its task. It is usually volatile, and is lost if a power interruption occurs. It also is the faster than secondary. This guide will concern itself with only three types of prime memory, ROM, SRAM, and DRAM.

ROM is short for read-only memory. This type of memory is read from, but not written to. It is used where the information put in it must be remembered even after power is turned off. Plain ROM is usually mask programmed at the factory, and can never be changed. This type of permanent memory is fine for large production runs, but is not suited where a memory change might need to be made during development. ROMs are purchased in a variety of sizes, 2K, 8K, 16K, etc.

For permanent memory which might need to be changed during some phase of the system's life, you would use either EPROM or EEPROM type of permanent memory. Both of these are nonvolatile, but can be altered. EPROM is programmed in the field with what is called an EPROM "burner," which is a circuit that uses voltage pulses to "burn" the data in a memory location inside the EPROM. If it becomes necessary to erase the device, it is placed in a strong UV light source; and the contents of the EPROM are erased. A family of this type of memory is the 2700 series; it varies in size formats. Figure E 12.1-1 is a block diagram of the organization of a 2716 (2K x 8 unit). This series is used quite often due to ease of field programming.

It also is popular because it operates from a single 5 volt supply, costs little, and is quickly accessed. EPROMs are random access devices, as you can see by studying the block diagram of the 2716. This particular device is capable of storing 16,384 bits of information. The bits are organized 2K by 8; that is, 2,048 bytes of storage area. The X and Y decoders are for the random access of these 2K bytes of memory. The output enable and chip enable are used to select this particular chip from what might be a group of memory chips. The program logic portion is used in programming the device. The output buffer provides buffered outputs for system connection. For breadboarding and programming of this chip consult a manufacturer's data book.

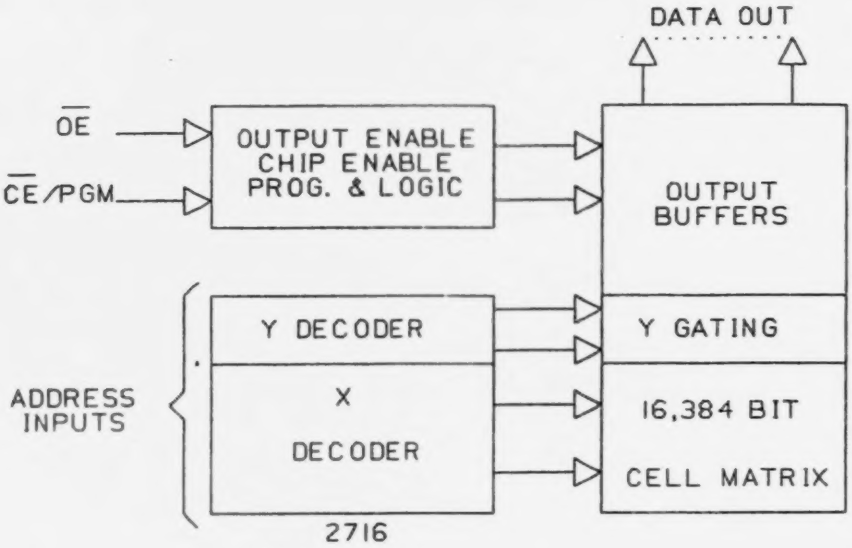


Figure E 12.1-2

SRAM, which is short for static ram is usually semiconductor type memory. SRAM uses flip-flops rather than capacitance for storage, therefore it does not need to be refreshed. Static RAM can be purchased in several logic families, depending on speed, power consumption, and size.

Figure E 12.1-3 is a unit cell of static TTL memory. The circuit is composed of two transistors to form a flip-flop. The cross-coupling between each transistor's input and output is similar to a NAND latch. Data can be input through the S and R inputs as active high set and reset inputs. The X and Y inputs are used to activate the device as chip select. Figure E 12.1-4 is a 7489 TTL SRAM chip. Its cell arrangement is 4 x 16 (4 bits at 16 different memory locations). TTL (bipolar) SRAM is fast, but it is not power efficient and the technology does not allow for great cell density.

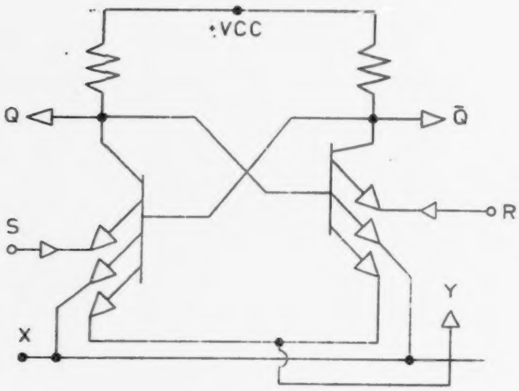


Figure E 12.1-3

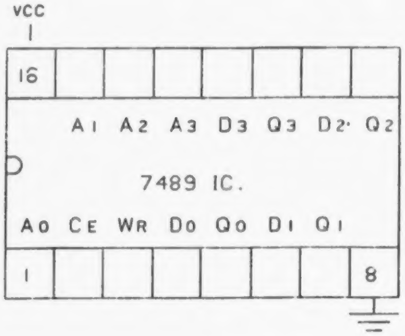


Figure E 12.1-4

An NMOS memory cell is shown in Figure E 12.1-5, and will provide much greater memory density and less power consumption than the TTL bipolar type. The two N-channel MOS FETS form a flip-flop and are cross-coupled like the TTL cell. Inputs and outputs are accessed through MOSFET switches that must be given a positive gate voltage to pass a signal. A NMOS 2102 IC is shown below for comparison to the 7489 TTL unit. The 2102 is a 16-pin package like the 7489; however, the 2102 has 1024 memory cells and the 7489 only has 64. This is quite a difference when you consider the chips are the same size. The 2102 NMOS unit is 1K x 1, meaning there are 1024 one bit memory cells. This is a very small SRAM chip by today's standards.

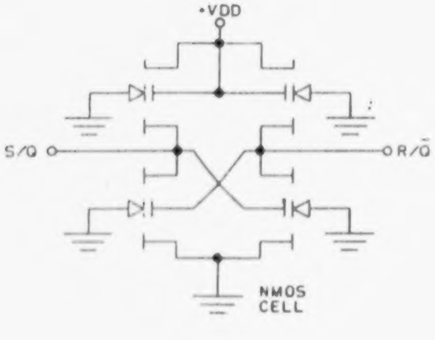


Figure E 12.1-5

CMOS SRAM is becoming very popular due to its low power consumption. It is finding its way into a lot of the portable battery operated equipment used today. In some applications CMOS is being used as nonvolatile memory.

Dynamic RAM, DRAM, memory cells store data in small integrated capacitors, or more likely by the capacitive nature of the MOS FET transistor. Data is stored as a charge on the input capacitance of a MOS transistor. Because any capacitor will have some leakage, the dynamic memory will tend to forget, and must be periodically refreshed. Figure E 12.1-6 is an example of a MOS DRAM cell. Dynamic memories are attractive because of their simple cell structure which allows for greater cell density. This feature also makes the DRAM cheaper than SRAM. The major problem with DRAM is the refresh circuitry which is required for its operation; however, newer devices are integrating this refresh circuitry on the chip, making the DRAM appear as if it were static memory.

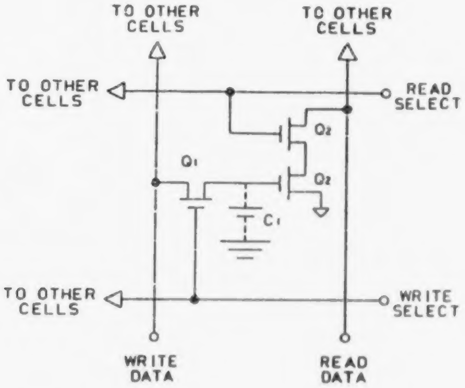


Figure E 12.1-6

This guide has only covered a few of the many different types of memory devices. Memory is probably one of the fastest changing areas in semiconductor technology, and therefore one of the hardest to keep current with. It would serve you well to investigate as many sources of information on memory as you possibly can. This will help you to acquire the information on memory you will need as an electronics technician, and also give you an appreciation of how rapid this area of electronics is changing.

ACTIVITY SHEET

E 12.2

MEMORY

Fill in the blanks for each of the following acronyms:

1. SRAM ____________ ____________ ____________ ____________
2. DRAM ____________ ____________ ____________ ____________
3. RAM ____________ ____________ ____________ ____________
4. ROM ____________ ____________ ____________ ____________
5. PROM ____________ ____________ ____________ ____________
6. EPROM ____________ ____________ ____________ ____________
7. EEPROM ____________ ____________ ____________ ____________
8. List some advantages of bipolar SRAM and give some disadvantages.
9. List some advantages of DRAM and also some disadvantages.
10. Using the memory data books or catalogs in your lab list some of the more common DRAM CHIPS with their cell arrangement (1K x 1).
11. Repeat step number 10 for common SRAM chips.
12. Using EPROM and EEPROM data books, complete a list of all the chips available in the 2700 series and the 2800 series.

ACTIVITY SHEET E 12.2

ANSWER SHEET

1. Static read/write memory
2. Dynamic read/write memory
3. Read/write memory (random access type) can be used to mean SRAM or DRAM.
4. Read-only memory usually factory masked
5. Programmable read-only memory
6. Erasable programmable read-only memory
7. Electrically erasable programmable read-only memory
8. Advantages = fast; disadvantages = power hunger, less density
9. Advantages = high density, high power, disadvantage=refresh circuits
10. This will depend on student's selection and the books available
11. See 10.
12. 2700 series will run from 1K up to whatever your latest data book shows. 2800 series will depend on data books you have in your lab.

PROGRAM: ELECTRONICS

TASK: ANALYZING DIGITAL ELECTRONIC CIRCUITS

TASK # E 12.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ____________

TERMINAL PERFORMANCE OBJECTIVE:

Analyze, construct, and troubleshoot memory circuits.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

MEMORY CIRCUITS

E 12.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
1.	Was the circuit wired according to the schematic?	Y	N
*2.	Does the circuit function properly?	Y	N
*3.	Was necessary data recorded?	Y	N
4.	Was the correct equipment used?	Y	N
5.	Was the equipment used properly?	Y	N
*6.	Were safety precautions followed?	Y	N
*7.	Was equipment returned to proper storage area?	Y	N

TOTAL POINTS POSSIBLE ___

POINTS NEEDED FOR MASTERY ___

SCORE ___

EXAM E 12.3

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on memory circuits. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer a minimum of 8 out of 10 items correctly, 80%.

MATCH THE MEMORY CHARACTERISTICS TO THE MEMORY TYPE LISTED BELOW.

1. Mask programmed at the factory, used for high production runs.

2. Nonvolatile memory and extremely easy to reprogram.

3. Nonvolatile memory, field programmable, but can only be programmed once.

4. To erase its memory you use a strong UV light source.

A. EEPROM B. ROM

C. EPROM D. RAM E. PROM

MATCH THE FOLLOWING MEMORY CHARACTERISTICS WITH THE PROPER MEMORY TYPE:

5. Very fast, power hungry and low cell density.

6. Very very low power requirements, but rather slow access time.

7. Low power consumption and very high cell density compared to bi-polar.

8. Must be refreshed or will lose its memory contents.

A. TTL SRAM B. DRAM

C. CMOS D. NMOS

9. Floppy disk would be classified under which of the memory categories.

A. Secondary memory B. Prime memory

10. ROM would more likely be found as the prime memory for the character set in an Apple computer than would EPROM.

A. True B. False

EXAM KEY E 12.3

1. B
2. A
3. E
4. C
5. A
6. C
7. D
8. B
9. A
10. A

ELECTRONICS

ANALYZING DIGITAL ELECTRONIC CIRCUITS

E 13: DAC AND ADC

TASK: Analyze, construct, and troubleshoot digital-to-analog and analog-to-digital converters.

PURPOSE: This learning guide will introduce some of the basic concepts of digital-to-analog and analog-to-digital converters. They will be defined and examples of each will be given. A-to-D and D-to-A conversion is a broad topic in electronics and only a very small portion of it will be covered by this guide. It will be up to you to investigate this topic in a much greater detail according to your memory requirements and needs.

OBJECTIVE: Given access to all necessary tools and equipment, you will analyze, construct, and troubleshoot digital-to-analog and analog-to-digital converters. To master this task, you must score 80% on a written exam and performance checklist.

ESTIMATED TIME: 20 HOURS

DAC AND ADC

LEARNING STEPS

E 13

READ:	Information Sheet E 13.1, "Digital-to-Analog and Analog-to-Digital Conversion."
READ:	Information on digital-to-analog and analog-to-digital conversion in one or more of the resources listed below.
COMPLETE:	Activity Sheet, E 13.2 on "Digital-to-Analog and Analog to Digital Conversion." Contact your instructor.
COMPLETE:	Lab performance on digital-to-analog and analog-to-digital conversion. Contact your instructor.
REVIEW:	All material covered by this learning guide.
COMPLETE:	Performance Checklist E 13.3. Contact your instructor.
COMPLETE:	Written Exam E 13.4. Contact your instructor.

DAC AND ADC

RESOURCES

E 13

1. CMOS DATA MANUAL (Motorola).
2. Brey, DIGITAL ELECTRONICS (Bobbs-Merrill, 1984).
3. Tokheim, DIGITAL ELECTRONICS TEXT AND ACTIVITY MANUAL (McGraw-Hill, 1984).
4. Tocci, DIGITAL SYSTEMS (Prentice-Hall, 1984).
5. DIGITAL TECHNIQUES STUDENT WORKBOOK (Heath Co., 1981).
6. Williams, DIGITAL TECHNOLOGY (SRA, 1982). 2nd Ed.
7. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Ed.
8. Texas Instrument TTL DATA MANUAL.

INFORMATION SHEET

E 13.1

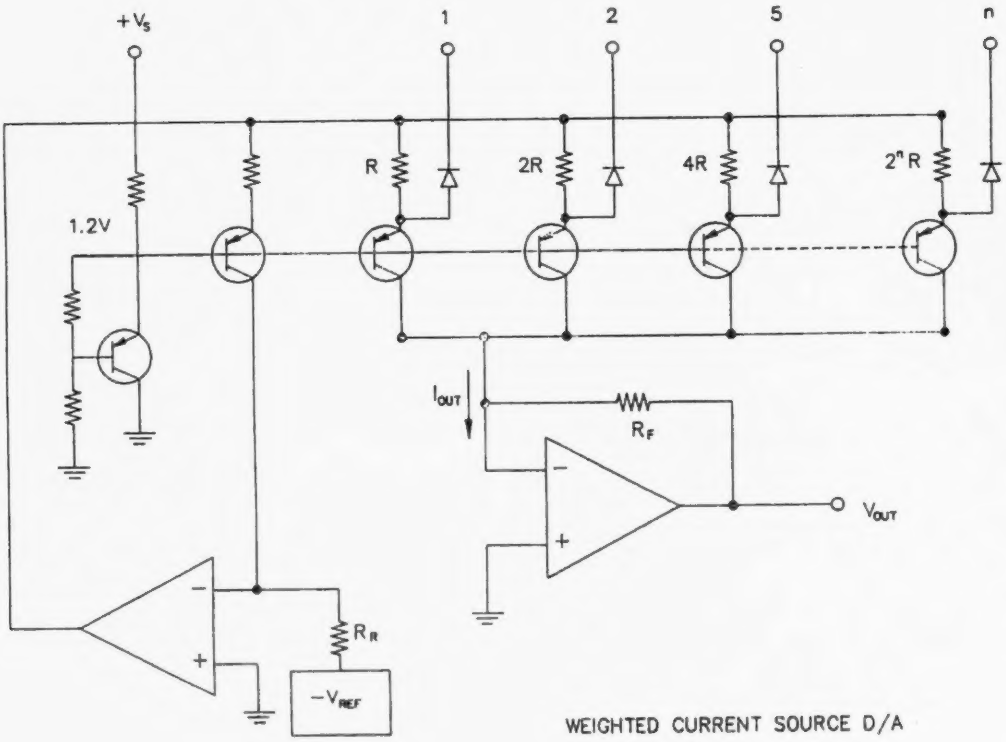
DIGITAL-TO-ANALOG AND ANALOG-TO-DIGITAL CONVERSION

Digital-to-Analog (D/A) and Analog-to-Digital (A/D) conversion is the process of converting from a digital signal/s to analog or from an analog signal back to digital. An example of this is found in the need to have a digital readout of an AC voltage. As you know the AC signal is constantly changing and is therefore analog, while the readout you desire is digital. The solution to this problem is to convert the AC analog signal into a digital signal which can be readout to your display for easy interpretation. The circuit required--an A/D converter.

Many times you will be required to go the other way, from a digital signal to an analog. An example of this might be a digital controller connected to a bank of motors or a piece of analog laboratory equipment. If this is the case, then a D/A converter would be called for.

There are many different circuit techniques used to implement D/A converters, but only a few popular ones are used today. Virtually all D/A converters in use are of the parallel type where all bits change simultaneously upon application of a digital input.

The most popular D/A converter design in use today is the weighted-current source circuit illustrated in Figure E 13.1-1. An array of switched-transistor current sources is used with binary weighted currents. The binary weighting is achieved by using emitter resistors with binary-related values of R, 2R, 4R, . . . 2^nR. The resulting currents are added together by the summing amp. The weighted current source design has the advantages of simplicity and high speed; however, implementing high resolution requires a wide range of emitter resistors, and very high value resistors will cause problems with temperature stability and switching speeds.



WEIGHTED CURRENT SOURCE D/A

Figure E 13.1-1

Another popular technique for D/A conversion is the R-2R ladder method. As shown in Figure E 13.1-2, the network consists of series resistors of value R and parallel resistors of value 2R. The bottom of each 2R resistor has a single-pole-double-throw electronic switch which connects the resistor to either ground or the output summing line. The operation of the R-2R ladder network is based on the binary division of current as it flows down the ladder. Examination of the ladder configuration reveals that at point "A" looking to the right, one measures a resistance of 2R; therefore, the reference input to the ladder has a resistance of R. At the reference input the current splits into two equal parts, since it sees equal resistances in either direction. Likewise, the current flowing down the ladder to the right continues to divide into two equal parts at each resistor junction.

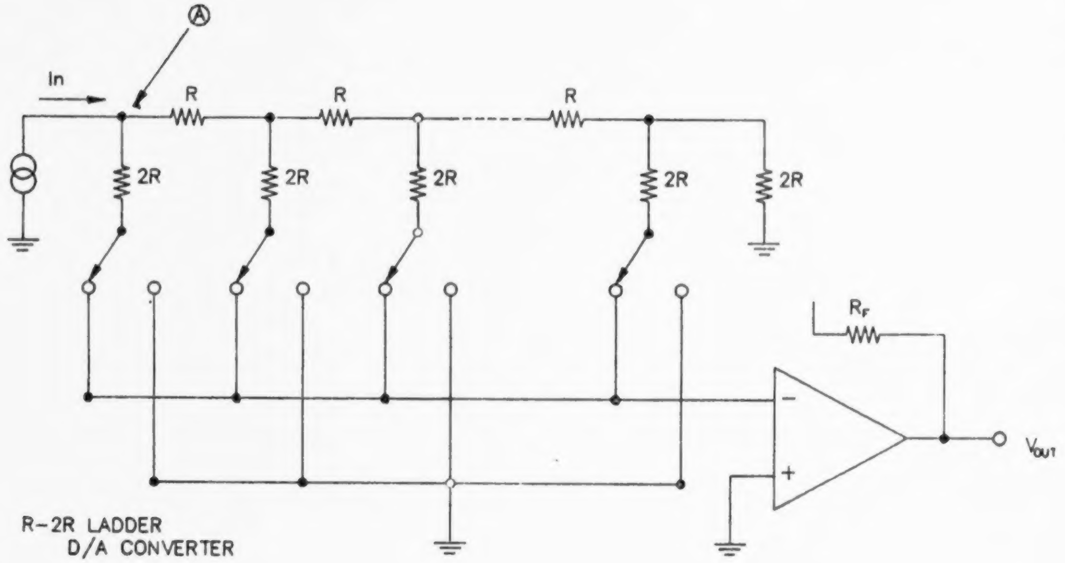


Figure E 13.1-2

The result is binary weighted currents flowing down each shunt resistor in the ladder. The digitally controlled switches direct the currents to either the summing line or ground. Assuming all bits are on as shown in Figure E 13.1-2, the output current is

$$Iout = Vref/R\ (1 - 2^{-n}).$$

As in the previous circuit, the output current summing line goes to an operational amplifier which converts current to voltage.

The advantage of the R-2R ladder technique is that only two values of resistors are required, which results in each matching and excellent temperature tracking. If relatively low resistor values are selected, then high speeds can be achieved.

In summary, the D/A converter is some form of resistor network configured to control the current flow, which in turn decodes the digital inputs to a group of currents which can then be summed and output as an analog voltage.

ANALOG-TO-DIGITAL CONVERSION

Because most analog-to-digital converters use a digital-to-analog converter as part of their circuitry, is the reason that D/A was covered first. Some of the more popular types of A/D converters are listed and defined below.

CHARGE-BALANCING A/D CONVERTER--An analog-to-digital conversion technique which employs an operational integrator circuit within a pulse-generating feedback loop. Current pulses from the feedback loop are precisely balanced against the analog input by the integrator, and the resulting pulses are counted for a fixed period of time to produce an output digital word. This technique is sometimes called quantized-feedback.

COUNTER TYPE A/D CONVERTER--A feedback method of A/D conversion whereby a digital counter drives a D/A converter, which generates an output ramp which is compared with the analog input. When the two are equal, a comparator stops the counter.

DUAL SLOPE A/D CONVERTER--An indirect method of A/D conversion whereby an analog voltage is converted into a time period by an integrator and reference and then measured by a clock and counter. The method is relatively slow but capable of high accuracy.

INDIRECT TYPE A/D CONVERTER--A class of analog-to-digital converter which converts the unknown input voltage into a time period and then measures this period.

INTEGRATING A/D CONVERTER--One of several types of A/D conversion techniques whereby the analog input is integrated with time. This includes dual-slope, triple-slope, and charge-balancing type A/D converters.

PARALLEL-TYPE A/D CONVERTER--An ultrafast method of A/D conversion which uses an array of 2^{n-1} comparators to directly implement a quantizer, where n is the resolution in bits. The quantizer is followed by a decoder circuit which converts the comparator outputs into binary code. This type is sometimes called a Flash-type A/D converter.

SINGLE-SLOPE A/D CONVERTER--A simple A/D converter technique in which a ramp voltage generated from a voltage reference and integrator is compared with the analog input voltage by a comparator. The time required for the ramp to equal the input is measured by a clock and counter to produce the digital output word.

SUCCESSIVE-APPROXIMATION A/D CONVERTER--An A/D conversion method that compares in sequence a series of binary-weighted values with the analog input to produce an output digital word in just n steps, where n is the resolution in bits; the process is efficient and is analogous to weighing an unknown quantity on a balance scale, using a set of binary standard weights.

VIDEO A/D CONVERTER--An ultra-fast A/D converter capable of conversion rates of 5MHz and higher. Resolution is usually 8 bits but can vary depending on the application.

As you can see there are a variety of A/D converters, and this list is by no means complete. This guide will only cover a couple of the simpler A/D converters, starting with the counter or tracking type. If you study the block diagram of the counter A/D in Figure 3, you will see that its operation is quite simple. A comparator "looks" at an analog input and a feedback from a D/A converter. The comparator's output controls the gate on two NAND gates, which in turn are used to control an up/down counter. The counter's output provides the digital output data and input to the D/A. When the track input is active, the comparator output will allow the pertinent counter to control the D/A converter.

As long as the analog input does not agree with the DAC, the counter will be gated on and a count will be fed to the D/A. It is only when the output from the D/A is equal to the analog input that the counter will be stopped and the digital count (conversion) displayed.

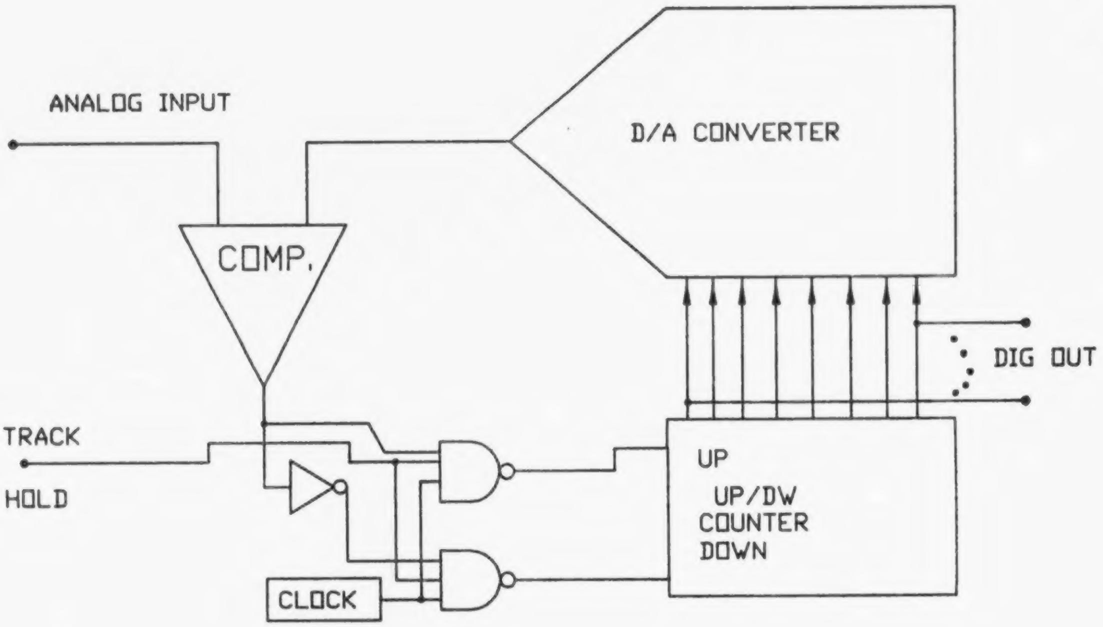


Figure E 13.1-3 [Tracking (Counter) Type A/D Converter]

By far the most popular A/D conversion technique in general use for moderate to high speed applications is the successive-approximation type. This type of converter falls in the general class of feedback A/D converters. A D/A converter is in the feedback loop of a digital control circuit which changes its output until it equals the analog input.

The operation of this converter is analogous to weighing an unknown on a laboratory balance scale using standard weights in a binary sequence such as 1, 1/2, 1/4, 1/8, . . . 1/n kilograms. A successive-approximation register (SRA) controls the D/A converter by implementing the weighing logic.

The basic operation is as follows. The SAR first turns on the MSB of the DAC and the comparator tests this output against the analog input. A decision is made by the comparator to leave the bit on or turn it off, after which bit 2 is turned on and a second comparison made. After n-comparisons the digital output of the SAR indicates all those bits which remain on and produces the desired digital code. Figure E 13.1-4 is a block diagram of Successive-Approximation A/D Converter.

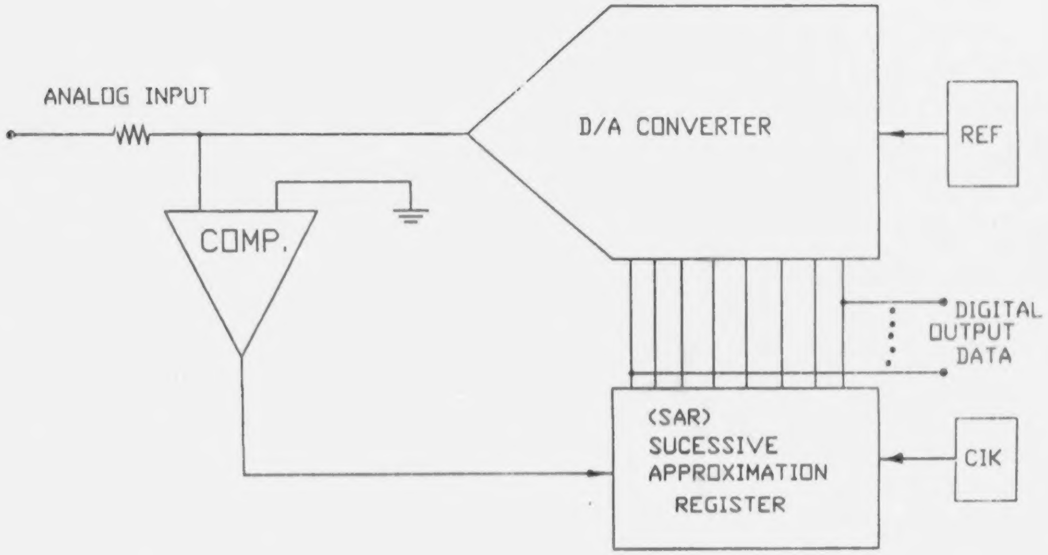


Figure E 13.1-4 [Successive Approximation A/D Converter]

Another class of A/D converter is the integrating type, which operates by an indirect conversion method. The unknown input voltage is converted into a time period, which is then measured by a clocked counter. A number of variations exist on the basic principle such as single-slope, dual-slope, and triple-slope methods.

The most popular of these methods is the dual-slope, which is slow, but has excellent linearity characteristics and is quite capable of rejecting input noise. Because of these characteristics the dual-slope type of A/D is used in digital panel meters, multimeters, and other measuring applications.

The dual-slope technique, is shown in Figure E 13.1-5. Conversion begins when the unknown input voltage is switched to the integrator input; at the same time the counter beings to count clock pulses and counts up to overflow. At this point the control circuit switches the integrator until the output is back to zero. Clock pulses are counted during this time until the comparator detects the zero crossing and turns them off. The counter output is then the converted digital word. The digital output word represents the ratio of the input voltage to the reference voltage. Figure E 13.1-6 is a block diagram of a dual-slope A/D.

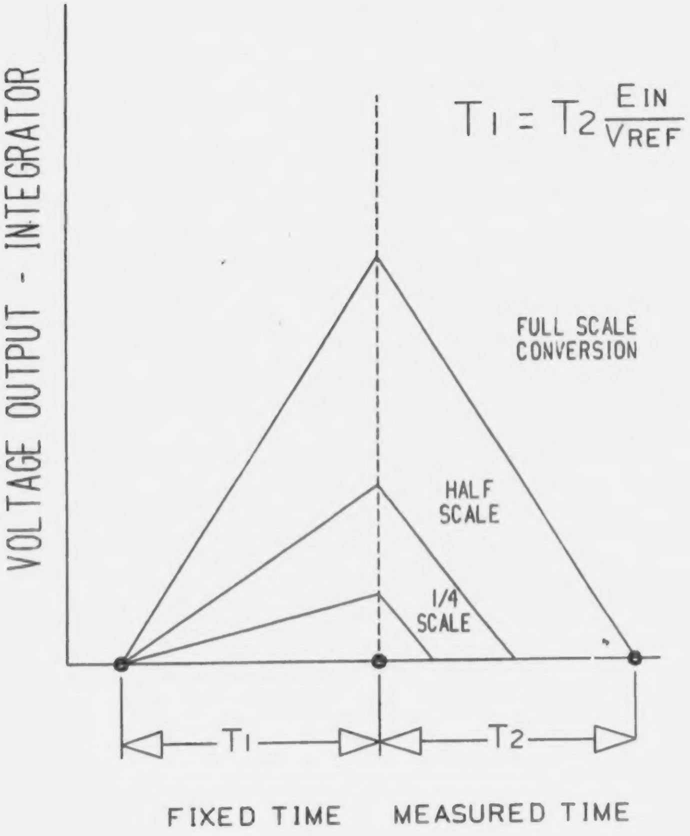


Figure E 13.1-5

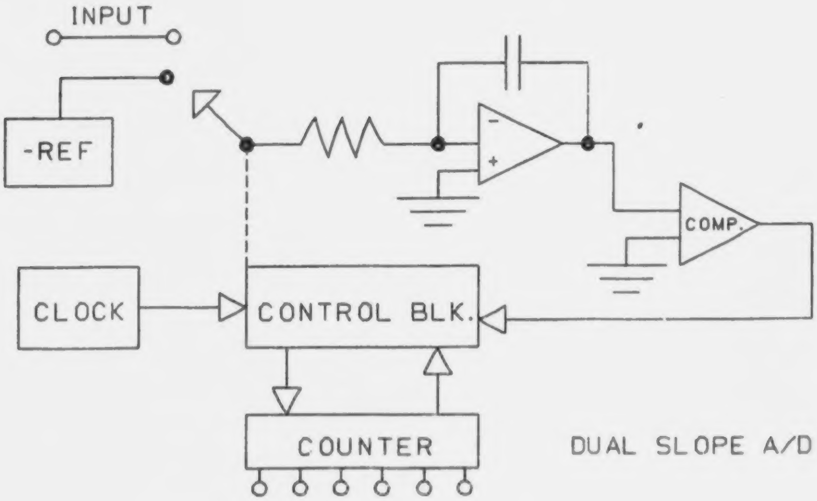

INPUT
-REF
COMP.
CLOCK
CONTROL BLK.
COUNTER
DUAL SLOPE A/D

Figure E 13.1-6

This concludes the coverage of D/A and A/D converter. This guide has only touched on the topic. There are many good reference texts and application notes which pertain to converters; take some time and extend your education in this area of electronics.

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ACTIVITY SHEET

E 13.2

D/A AND A/D CONVERTERS

Define the following terms:

1. A/D Converter
2. Auto Zero
3. Clock
4. Conversion time
5. Conversion rate
6. D/A Converter
7. Full Scale Range (FSR)
8. Hysteresis Error
9. Integral linearity error
10. R-2R ladder network
11. Reference circuit
12. Resolution.

ACTIVITY SHEET E 13.2

ANSWER SHEET

1. A/D Converter: Analog-to-digital converter. A circuit which converts an analog voltage or current into an output digital code.

2. Auto Zero: A stabilization circuit which serves as an amplifier or A/D converter input offset to zero during a portion of its operating cycle.

3. Clock: A circuit in an A/D converter that generates timing which synchronizes the operation of the converter.

4. Conversion time: The time required for an A/D converter to complete a single conversion to specified resolution and linearity for a full-scale analog input change.

5. Conversion rate: The number of repetitive A/D or D/A conversions per second for a full-time scale change to specified resolution and linearity.

6. D/A Converter: Digital-to-Analog converter. A circuit which converts a digital code word into an output analog voltage or current.

7. Full Scale Range (FSR): The difference between maximum and minimum analog values for an A/D converter input or D/A converter output.

8. Hysteresis Error: The small variation in analog transition points of an A/D converter whereby the transition level depends on the direction from which it is approached. In most A/D converters this hysteresis is very small and is caused by the analog comparator.

9. Integral linearity error: The maximum deviation of a data converter transfer function from the ideal straight line with offset and gain errors zeroed. It is generally expressed in LSB's or percent of full scale range.

10. R-2R ladder network: An array of matched resistors with series values of R and shunt values of 2R in a standard ladder circuit configuration.

11. Reference circuit: A circuit which produces a stable output voltage over time and temperature for use in A/D and D/A converters.

12. Resolution: The smallest change that can be distinguished by an A/D converter or produced by a D/A converter. Resolution may be stated in percent of full scale, but is

commonly expressed as the number of bits, n, where the converter has 2^n possible states.

PROGRAM: ELECTRONICS

TASK: DAC AND ADC

TASK # E 13.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ____________

TERMINAL PERFORMANCE OBJECTIVE:

Analyze, construct, and troubleshoot digital-to-analog and analog-to-digital converters.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

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ELECTRONICS

DAC AND ADC

E 13.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the circuit wired according to the schematic?	Y N
*2.	Does the circuit function properly?	Y N
*3.	Was necessary data recorded?	Y N
4.	Was the correct equipment used?	Y N
5.	Was the equipment used properly?	Y N
*6.	Were safety precautions followed?	Y N
*7.	Was equipment returned to proper storage area?	Y N

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

SCORE ____

EXAM E 13.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on D/A and A/D. Each of the questions or incomplete statements is true or false. Place the letter associated with that choice (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer a minimum of 8 out of 10 items correctly, 80%.

EXAM E 13.4 CONT'D.

1. Most A/D converters employ a D/A converter.

   A. True
   B. False

2. In a standard resistor-ladder network, the larger the binary number the smaller the current which flows.

   A. True
   B. False

3. In a R2R ladder network there are only two values of resistors needed.

   A. True
   B. False

4. Most D/A converters use some form of difference amp.

   A. True
   B. False

5. In a counter type A/D converter, when the analog input is greater than the feedback from the D/A, the counter is stopped.

   A. True
   B. False

6. An 8-bit A/D has greater resolution than a 12-bit A/D.

   A. True
   B. False

7. The successive-approximation type A/D method is analogous to weighing an unknown on a laboratory scale.

   A. True
   B. False

8. A dual-slope A/D is classed as an integrating type.

   A. True
   B. False

9. The dual-slope A/D is used quite often in digital panel meters.

   A. True
   B. False

10. In the dual-slope A/D, the digital output word represents the ratio of input voltage to the reference voltage.

    A. True
    B. False

EXAM KEY E 13.4

1. A
2. B
3. A
4. B
5. B
6. B
7. A
8. A
9. A
10. A

ELECTRONICS

ANALYZING DIGITAL ELECTRONIC CIRCUITS

E 14: ANALYZE THE OPERATION OF A TYPICAL MICROPROCESSOR SYSTEM

TASK:	Analyze the operation of a typical microprocessor system.
PURPOSE:	Microprocessors are being used in more and more electronic equipment. Therefore, it is necessary for the electronics technician to know as much about these devices as possible. This learning guide will provide an introduction to some fundamentals of microprocessors.
OBJECTIVE:	Given a written exam, you will analyze the operation of a typical microprocessor system. To master this task you must score 80% on a written exam.

ESTIMATED TIME: 5 HOURS

ANALYZE THE OPERATION OF A TYPICAL MICROPROCESSOR SYSTEM

LEARNING STEPS

E 14

READ:	Information Sheet E 13.1, "Introduction to the Microprocessors."
READ:	Information on microprocessors in one or more of the resources listed below.
COMPLETE:	Activity Sheet, E 14.2, "Introduction to the Microprocessors."
REVIEW:	All material covered by this learning guide.
COMPLETE:	Written Exam E 14.3 on microprocessors. Contact your instructor.

ANALYZE THE OPERATION OF A TYPICAL MICROPROCESSOR SYSTEM

RESOURCES

E 14

1. Intel, MCS-80/85 FAMILY USERS MANUAL (1979).
2. Zumchak, MICROCOMPUTER DESIGN AND TROUBLESHOOTING (Howard Sams, 1982).
3. Leventhal & Walsh, MICROCOMPUTER EXPERIMENTATION WITH THE INTEL SDK 85 (Prentice Hall, 1980).
4. Hall, MICROPROCESSOR AND DIGITAL SYSTEMS (McGraw-Hill, 1983) 2nd edition.
5. Bery, MICROPROCESSOR AND HARDWARE INTERFACING & APPLICATIONS (Merrill, 1984).
6. Intel, PERIPHERAL DESIGN HANDBOOK (1981).
7. Goody, THE INTELLIGENT MICROCOMPUTER (SRA, 1982).
8. Larsen, Titus & Titus, 8085A COOKBOOK (Howard Sams, 1982).
9. Titus, Tony, Larsen & Titus, 8080/8085 SOFTWARE DESIGN BOOK I (Howard Sams, 1982).
10. Titus, Tony, Larsen & Titus, 8080/8085 SOFTWARE DESIGN BOOK II (Howard Sams, 1981).

INFORMATION SHEET

E 14.1

INTRODUCTION TO MICROPROCESSORS

An introduction to microprocessors will start with an introduction to some terms commonly used to describe the microprocessor and its operation.

Central Processing Unit:	The main control element of any computer. The element that allows all the other parts of the computer to work together.
Microprocessor:	A CPU that has been manufactured as a single IC, using large scale-integration techniques.
Program Counter:	The section of a microprocessor that determines which instruction should be acted upon next.
Program:	A sequence of instructions, which is designed to perform a specific task.
Instruction:	A microprocessor command, i.e., stop, jump, add, etc.
Instruction Decoder:	An area in the processor which decodes and interprets the machine instruction.
Stack Pointer:	A special-purpose register inside the processor used to keep track of present address when a subroutine is called.
Arithmetic Logic Unit:	A portion of the CPU which performs arithmetic and logical operations.
Accumulator:	A special register used to store data operated on by the ALU.
Flag Register:	A register used to hold status information pertaining to the CPU.
General Purpose Registers:	Registers used to hold temporary information for general purpose use.

System Clock:	A train of pulses with specific rate, used to synchronize the transfer of data into and out of the microprocessor.
Internal Bus:	A group of internal wires carrying the same type of information, connected to the inputs and outputs of several registers or other sections of a microprocessor.
External Bus:	A group of external wires or circuit traces used to carry information between memory, input/output devices, and the microprocessor. Usually grouped in three bus groups: address, data, and control.
Instruction Cycle:	The time required to fetch an instruction from memory, decode it, and perform the prescribed operations. Usually further divided into a fetch cycle and execution cycle.

Now that we have defined some microprocessor terms let us turn our attention to the basic architecture of an 8-bit microprocessor. Figure E 14.1-1 is an example of a typical 8-bit machine. Machine is a common term used to refer to the microprocessor. It is referred to as an 8-bit machine because its data bus is 8-bits or 1-byte wide. Some of the newer machines are 16-and 32-bit machines. This guide will use the 8-bit microprocessor as its example because so many units of this kind are in service.

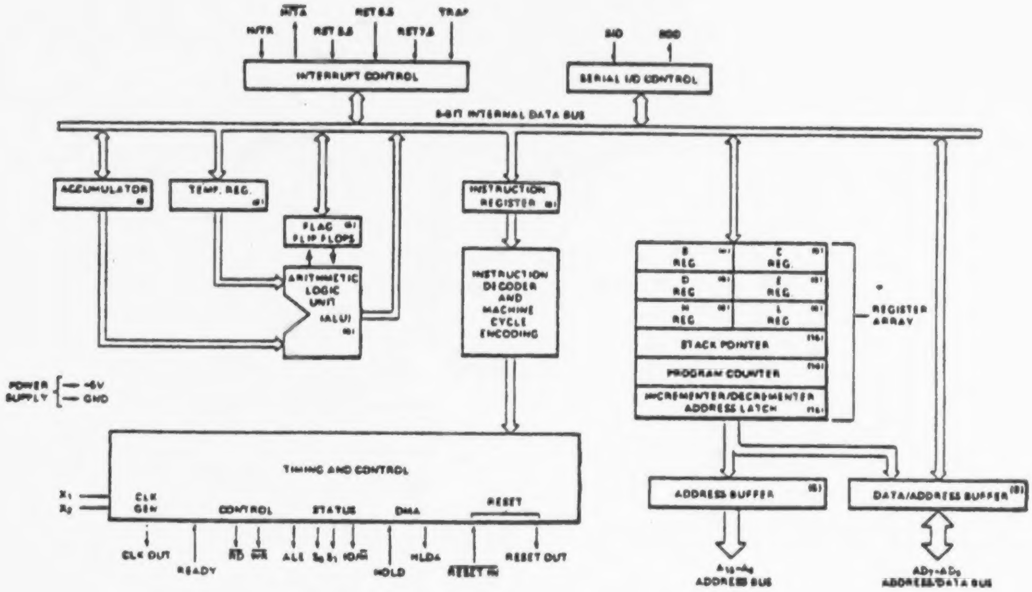
INTR
$\overline{INTA}$
RST 5.5
RST 6.5
RST 7.5
TRAP
SID
SOD
INTERRUPT CONTROL
SERIAL I/O CONTROL
8-BIT INTERNAL DATA BUS
ACCUMULATOR (8)
TEMP. REG. (8)
FLAG (5) FLIP FLOPS
ARITHMETIC LOGIC UNIT (ALU) (8)
INSTRUCTION REGISTER (8)
INSTRUCTION DECODER AND MACHINE CYCLE ENCODING
B REG (8)
C REG. (8)
D REG (8)
E REG. (8)
H REG (8)
L REG (8)
STACK POINTER (16)
PROGRAM COUNTER (16)
INCREMENTER/DECREMENTER ADDRESS LATCH (16)
REGISTER ARRAY
POWER SUPPLY
+5V
GND
TIMING AND CONTROL
X1
X2
CLK GEN
CONTROL
STATUS
DMA
RESET
CLK OUT
READY
$\overline{RD}$
$\overline{WR}$
ALE
S0
S1
IO/$\overline{M}$
HOLD
HLDA
$\overline{RESET IN}$
RESET OUT
ADDRESS BUFFER (8)
DATA/ADDRESS BUFFER (8)
A15-A8 ADDRESS BUS
AD7-AD0 ADDRESS/DATA BUS

Figure E 14.1-1

The lines with arrowheads are internal data buses of various widths. Note that the accumulator is tied to the 8-bit internal data bus, because most of the data into the processor will be brought in through the accumulator. Also note the accumulator is positioned very near the ALU, because the accumulator will be used to store the results of all logic and arithmetic operations.

The flag register is also near the ALU, because it will be used to flag the condition of the accumulator and the processes which occur in the ALU. Tied directly to the 8-bit internal data bus is the instruction register; it will receive instructions; from the data bus and pass them onto the instruction decoder.

After the instruction has been decoded, its execution will be handled by the timing and control block of the microprocessor. If you study the diagram, you will see this section of the processor provides nearly all of the timing and control between the processor and all of the external devices. To the right of the instruction register are the general purpose registers, which are 8-bits wide and grouped in pairs so they may be used to store and handle 16- bit words. Below the general purpose registers are the stackpointer, the program counter, and address latch; these are all special purpose registers who functions have been defined in the list of terms at the beginning of this information sheet.

The two blocks of the microprocessor not yet covered are the interrupt control and serial I/O control. The interrupt control is used to interrupt the processor and have it interact with a slower external device. Serial I/O control is used for serial transfer of data into and out of the microprocessor.

As you can see from the diagram, the microprocessor is a little more complicated than a counter or an encoder chip; however, with a little study and some practical experience working with a processor you will soon develop an understanding of how they work.

Up to this point our discussion has only covered the hardware aspects of a microprocessor. What makes a microprocessor unique among the digital devices you have studied so far, is its ability to be programmed. Each microprocessor has a set of instructions built into its hardware, as few as 50 or as many as a 100. The more instructions a processor has the more things it can be programmed to do. The number of instructions and their complexity will depend on the microprocessor you are using.

These microprocessor instructions are sometimes referred to as machine code; machine code used to do a task is often called a machine-language program. The microprocessor is only as smart as the person who is programming it to do something. In order for the machine to do anything at all it must be programmed, which means that you, the technician, will have to learn something about machine-language programming. Don't worry about this task, for there are many people and many reference books available to help you get started with machine-language programming.

In summary you can see that the microprocessor is more than just hardware; it is smart hardware. In the past if a circuit was designed to do a particular function, and if the function changed, then the circuit had to be scrapped and a new one built. Today, if the function of the circuit changed, it is quite possible the only modification which might have to be made is in the program software. It is this flexibility which makes the microprocessor popular in new designs. You are probably starting to see the importance of microprocessors, and are beginning to realize the fact that as a technician you are going to have to understand both the hardware and software aspects of these devices. Do not worry, for with some study these devices will become easy to understand and use.

ACTIVITY SHEET

E 14.2

INTRODUCTION TO MICROPROCESSORS

Listed below are some statements. Fill in the blank/blanks for these statements:

1. The main control element of any computer is the ____________.
2. The CPU is capable of performing tasks such as counting, arithmetic, or performing __________ functions.
3. The CPUs of most microcomputers are _________________.
4. The element in a microprocessor that determines which instruction should be acted on next is called the __________.
5. A sequence of instructions designed to perform a specific task is called a (an) ______________.
6. After the CPU fetches an instruction, the instruction is temporarily stored in the ______________.
7. The section of the CPU that performs all the arithmetic and logical instructions required by the program is the ________.
8. Information on the status of the CPU following certain ALU operations is found in the ________________.
9. A flag, or status bit can be used to ____________ a program.
10. In a computer, all logic operation occur in a defined sequence under the control of a (an) ___________________.
11. The time required to fetch an instruction, decode it, and perform prescribed operations is called a (an) ____________.
12. The common wire paths that connect the various microprocessor components are called a (an) ______________.
13. The number of wires in a bus is called the ______________.

ACTIVITY SHEET E 14.2

ANSWER SHEET

1. Central processing unit
2. Logic
3. Microprocessors
4. Program counter
5. Program
6. Instruction register or instruction decoder
7. ALU arithmetic logic unit
8. Flag or status register
9. Branch
10. System clock
11. Instruction cycle
12. Bus or buses
13. Bus width

EXAM E 14.3

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on microprocessors. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, or D) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST!!! To master this exam you must answer a minimum of 8 out of 10 items correctly, 80%.

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1. The CPUs of most microcomputers are _______.

   A. ALUs
   B. Microprocessors
   C. Printed circuit assemblies
   D. Microcontrollers

2. The sort of minimum microcomputer used as the control element in instrumentation or process control systems is often called __________.

   A. an ALU
   B. a microprocessor
   C. a microcontroller
   D. a control CPU

3. The instruction register holds an instruction while the CPU's instruction decoder ________.

   A. fetches it
   B. loads it into the program counter
   C. goes through a subroutine
   D. interprets it

4. A type of program branching in which a sequence of instructions can be called from any point in a program simply by writing its address is called a (an) _________.

   A. instruction routine
   B. subroutine
   C. special program
   D. decrement

5. Which of the following is NOT a special-purpose register?

   A. ALU
   B. stack pointer
   C. program counter
   D. instruction register

6. Which section of the CPU performs all the arithmetic and logic functions?

   A. LIFO
   B. Microcontroller
   C. ALU
   D. Instruction decoder

7. How many operations can a computer perform at one time?

   A. 2n
   B. one
   C. two
   D. bit capacity * CPU capacity

8. All of the microprocessor's functions are synchronized by the:

   A. ALU
   B. flag registers
   C. status bits
   D. clock

9. The time required to fetch an instruction, decode it, and perform prescribed operations is called a (an):

   A. clock cycle
   B. memory cycle
   C. instruction cycle
   D. operation cycle

10. The number of wires in a bus is usually determined by:

   A. The type of system clock used
   B. the word size of the registers
   C. whether a bus is internal or external
   D. The participants to which it is attached

EXAM KEY E 14.3

1. B
2. C
3. C
4. B
5. A
6. C
7. B
8. D
9. C
10. B

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (8085)

F1-1: MICROCOMPUTER AND MICROPROCESSOR SYSTEMS

TASK: Describe the operation of microcomputer and microprocessor systems.

PURPOSE: Before you start a study of microprocessors, you should have an understanding of what a microprocessor is, and how it is used in microcomputer systems. After completing this learning guide, you will be familiar with microprocessor terminology, family support devices, machine language programming, operation, and microprocessor types. This guide will only provide an introduction to these areas of study, you will be gaining more information on these topics as your study of microprocessors continues.

OBJECTIVE: Given a written exam, you will describe the operation of microcomputer and microprocessor systems. To master this task you must score 80% on a written exam.

ESTIMATED CLASS TIME: 5 HOURS

MICROCOMPUTER AND MICROPROCESSOR SYSTEMS

LEARNING STEPS

F1-1

READ: Information Sheet F1-1.1 on "Microcomputer and Microprocessor Systems."

READ: Information on microcomputer and microprocessor systems from the following resource list.

COMPLETE: Activity Sheet F1-1.2 on "Microcomputer and Microprocessor Systems."

COMPLETE: Lab performances on microcomputer and microprocessor systems. Contact your instructor.

REVIEW: All materials covered in this learning guide.

COMPLETE: Performance Checklist F1-1.3.

COMPLETE: Written exam F1-1.4 on "Microcomputer and Microprocessor Systems." Contact your instructor.

MICROCOMPUTER AND MICROPROCESSOR SYSTEMS

RESOURCES

F 1-1

1. MCS-80/85 FAMILY USERS MANUAL (Intel, 1979).
2. Zumchak, MICROCOMPUTER DESIGN AND TROUBLESHOOTING (Howard Sams, 1982).
3. Leventhal & Walsh, MICROCOMPUTER EXPERIMENTATION WITH THE INTEL SDK 85 (Prentice Hall, 1980).
4. Hall, MICROPROCESSOR AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Edition.
5. Bery, MICROPROCESSOR AND HARDWARE INTERFACING & APPLICATIONS (Merrill, 1984).
6. PERIPHERAL DESIGN HANDBOOK (Intel, 1981).
7. Goody, THE INTELLIGENT MICROCOMPUTER (SRA, 1982).
8. Larsen, Titus, & Titus, 8085A COOKBOOK (Howard Sams, 1982).
9. Titus, Rony, Larsen & Titus, 8080/8085 SOFTWARE DESIGN BOOK I (Howard Sams, 1982).
10. Larsen, Titus, & Titus, 8080/8085 SOFTWARE DESIGN BOOK II (Howard Sams, 1981).

INFORMATION SHEET

F1-1.1

INTRODUCTION TO MICROPROCESSORS

Before beginning work on the microprocessor study the terms below and become familiar with their meaning.

Assembly language: A programming language comprised of mnemonic phrases each of which represents an assembly of machine (binary) instructions.

Central processing unit: This unit directs the flow of information through a computer, determines what operations are to be performed and when they are to take place, and performs the mathematical operations.

Bus: Usually a group of wires over which digital information is transmitted from one of several sources to one of several destinations. Commonly found in digital systems.

Input/Output (I/O) ports: Device terminals that provide electrical access to a system such as a microcomputer. These ports are where the I/O information contacts the "outside world."

Instruction: Information which when properly coded causes a computer to perform a particular operation.

Instruction set: A list of all the instructions a computer or microprocessor can execute; one means of describing a machine's capability.

Machine language: The most basic of all programming languages; binary words directly intelligible to a computer without translation; "computerspeak."

Microcomputer chip: An IC version of a computer containing a microprocessor, memory and I/O ports.

Microprocessor: An IC central processing unit (CPU), comprising a control unit, and ALU and associated registers.

Program: An organized list of computer instructions for the purpose of solving a particular problem.

Program counter: A register in the CPU containing the address of the next instruction to be being executed.

INFORMATION SHEET F1-1.1 CONT'D.

RAM (random access memory): A digital memory in which any particular memory cell can be accessed independently, a temporary memory.

ROM (read only memory): A digital memory which, after its initial programming by the manufacturer, can only be read and no longer written upon; a permanent memory.

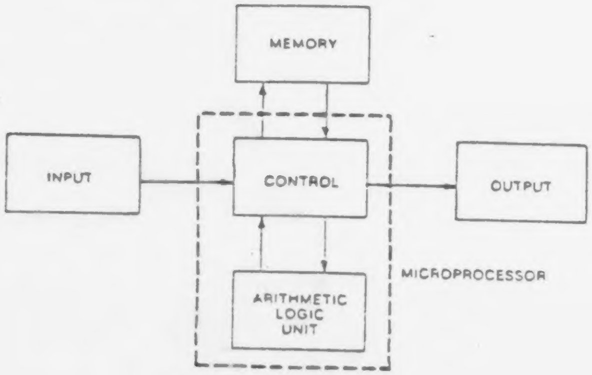
INFORMATION SHEET

F1-1.1

"MICROCOMPUTER AND MICROPROCESSOR SYSTEMS"

Integrated circuit technology has developed to the point where it is now possible to fabricate entire computer central processing units in a large-scale integrated packages. These devices are known as microprocessors.

Microprocessors are most often used as integral parts of microcomputer systems. There they function as the computer's CPU and control the transfer of information in and out of the computer and to and from the memory, as well as handling the actual processing of the data. As shown in Figure F1-1.1-1, a computer contains three major building blocks. A microprocessor, therefore may be thought of as being one-third of a computer.



Anatomy of a Computer

Figure F1-1.1-1

Since a microprocessor is an integral part of a computer, its characteristics may be best understood by examining the operation of a typical computer. In its simplest form, a computer may be thought of as a highly versatile general purpose machine, which may be programmed (given a specific list of instructions) to do a particular job. The program is stored in the memory along with any data which will be needed.

In dedicated, fixed-program applications the program is often stored in ROM, with the data to be used stored in RAM.

Referring again to Figure F1-1.1-1, the input/output block in the diagram handles communication between the microprocessor and the outside world. Devices such as keyboards, teletypes, LED displays and video terminals are connected to this I/O interface. Within the central processing unit (CPU) of the computer is an important temporary storage register known as the accumulator. This register is the heart of the computer and many major data processing operations utilize it. The control unit contains two other important registers, the instruction register and program counter. The instruction register holds the present instruction being executed by the computer, and the program counter keeps track of which instruction the computer will execute next.

Instructions are coded messages entered in the machine by the programmer and decoded by the computer in order to interpret their meaning. For a computer to be useful it must be capable of handling many different types of instructions.

Some of the more basic instructions include those which permit the addition, subtraction, and movement of data as well as input/output and logical operations on the data. It should be noted that there are no multiply or divide instructions in smaller computers. To perform these operations on smaller units the user must write special programs employing successive additions for multiplication and successive subtractions for division.

To solve a problem on a computer, the user must express it in the language of that machine. The resulting list of instructions is known as a computer program. This list tells the computer exactly what to do and in what order to do it. Unfortunately, while the user would probably prefer to write his programs in English, the computer likes binary. In fact, in primitive machines the programmer had to program them in binary via front-panel switches. The futility of this method can best be appreciated by examining the partial program listing in the left column of Figure F1-1.1-2 and by considering the difficulty of entering not just the four lines shown but perhaps as many as four thousand lines of code. An improvement on this method is to key in the program by using octal or hexadecimal coding. Hexadecimal coding replaces each group of four bits in the computer word by its equivalent hex character which makes the computer words much easier to enter, remember, and view on displays and program listings.

In writing long programs even hexadecimal coding soon becomes tedious, since there is no resemblance between the hex code symbols used and the English interpretation of the instruction.

The fatigue on the programmer and the probability of error can be reduced considerably by representing each machine instruction by a mnemonic or shorthand symbolic notation indicative of the operation to be performed. For example, instead of keying in 3A (or worse yet 00111010 as shown in Figure F1-1.1-2) you can load the accumulator by typing in LDA. This type of programming is known as assembly language programming. A special program called an assembler is required which translates these mnemonics into their equivalent binary code.

Binary Code	Hexadecimal Equivalent	Mnemonic	Comment
00111010	3A	LDA 71h	Load accumulator with the contents of location 0071
01110001	71		
00000000	00		
11000110	C6	ADI 23h	Add 23 to the accumulator
00100011	23		
00110010	32	STA 50h	Store result in location 0050
01010000	50		
00000000	00		
01110110	76	HLT	Halt

Figure F1-1.1-2. Comparison of Programming Methods

To understand how a microcomputer operates, consider the sample program illustrated in Figure F1-1.1-3. This basic program involves the addition of two numbers which have been previously stored in memory at locations 30 and 31, and the storage of the answer in memory at location 40. Figure F1-1.1-3 shows the physical organization of the memory. The program is located from addresses 0000 to 000B, the data to be added are at memory locations 0030 and 0031, and the final answer will be found at location 0040.

```
Address  Contents  Mnemonic        Comments

 0000     3A3000    LDA 30    ;Load accum. from location 0030h
 0003     47        MOV B,A   ;Move contents of acc. to reg B
 0004     3A3100    LDA 31    ;Load acc from location 0031h
 0007     80        ADD B     ;Add reg B to the accumulator
 0008     324000    STA 40    ;Store acc in location 0040h
 000B     76        HLT       ;Halt execution
  .
  .
 0030     05      {Data is stored here}
 0031     03
  .
  .
 0040     ??      {Answer will be stored here}
```

Figure F1-1.1-3. Memory Contents at Start of Program

INFORMATION SHEET F1-1.1 CONT'D.

The mode of operation of the computer is to fetch an instruction, figure out its meaning, and execute it. During a fetch, the instruction to be used is taken from memory at the address specified by the contents of the program counter and placed in the instruction register. Since the PC is initially zero, the first instruction fetched in this example will be LDA 30. Next, the control unit of the computer figures out the meaning of this instruction, and then during the execute cycle places the contents of location 30 (the number 5) into the accumulator (Figure F1-1.1-4). At this point the contents of the PC are incremented by three (LDA is a 3 byte instruction) to 0003 and the next instruction cycle begins with a fetch from memory location 0003. The program continues along in this fashion until the stop (HLT) is executed, halting further operation of the machine and completing the program.

Address	Instruction	Accumulator	Reg. B	Memory 0040
0001	LDA 30	05	??	??
0003	MOV B,A	05	05	??
0004	LDA 31	03	05	??
0007	ADD B	08	05	??
0008	STA 40	08	05	08
000B	HLT	08	05	08

Figure F1-1.1-4. Sample Computer Problem Execution

Frequently, certain groups of instructions may be used over and over again in writing computer programs. When this occurs it is useful to remove these instructions from the main program and organize them as a little program of their own known as a "subroutine." Thereafter, whenever the function performed by this group of instructions is required, the computer jumps to the portion of memory containing the subroutine. In order to find its way back to the main program after the subroutine is finished, the microprocessor saves the return address in a special area called the stack. The stack may be located either within the CPU as a fixed set of registers (hardware stack) or in main memory (software stack). The 8085 microprocessor uses a software stack. Hardware stacks, while easier to use, are fixed in size and generally have from three to ten stack levels, while software stacks, although requiring additional program statements, have a number of levels dependent on the amount of memory available.

Stacks are also used for handling "interrupts." An interrupt is a method by which an external device can cause the processor to suspend its present activity and go to a special program which will be used to service the interrupt. Interrupts are a very useful way to allow the CPU to communicate with slower devices like teletypes, printers, and terminals.

For example, when a keyboard wants to input a character to the CPU, it sends out an interrupt signal. The microprocessor stops what it is doing, goes over and reads in the character from the keyboard, and then goes back and continues its former activity. Using a process similar to that for subroutines, the interrupt return address is stored on the stack. In addition, since the interrupt service routine may change the contents of certain registers, the values of these registers prior to the interrupt may also be saved by "pushing" them onto the stack. On returning to the main program from the interrupt routine, the microprocessor then "pops" these register values off the stack. Machines having "vectored interrupt" capability can distinguish between several different kinds of interrupts and can directly branch to the appropriate service routine associated with each interrupt.

While interrupt techniques are useful for interacting with slow peripheral devices, "direct memory access" (DMA) is the preferred method for rapidly transferring large blocks of data between memory and fast serial-access devices like tape and disk drives. Without DMA, the transfer of data is quite slow, since the data must first pass through the accumulator before leaving the microcomputer. Where the data transfer is under DMA control, the address and data buses of the CPU are tri-stated and fast and external hardware performs the data transfer.

On its own, a microprocessor isn't capable of doing very much. It needs help, either in the form of a very large number of SSI/MSI devices, or from highly specialized microprocessor support chips. The most often used hardware may be grouped into seven main categories: CPU, memory devices (ROM, RAM, EPROM), buffers and clock generator/drivers, priority (vectored) interrupt systems, programmable timers, I/O ports and controllers, and DMA devices. These devices will be introduced and investigated later in other learning guides.

This learning guide has in no way covered all the material on microcomputers or microprocessor systems; however, there are many good text and reference books on the subject that you should study.

ACTIVITY SHEET

F1-1.2

MICROCOMPUTER AND MICROPROCESSOR SYSTEMS

On a separate sheet of paper perform the activities called for.

Define the terms listed below:

1. Assembly Language:
2. Machine Language:
3. CPU:
4. I/O
5. Instruction Set:
6. Microcomputer Chip:
7. Program:
8. RAM:
9. ROM:
10. BUS:

Fill in the blank(s):

11. Microprocessors are most often used as integral parts of ________________________ systems.
12. In dedicated fixed-program applications the program is often stored in _______________ or _______________.
13. I/O devices include _______________, _______________, and _______________.
14. Usually multiply and divide instructions are only included in the ___________________ machine instruction set.
15. DMA is short for _______________ _____________ ___________.

ACTIVITY SHEET F1-1.2

ANSWER SHEET

The definitions for 1 through 10 can be found at the beginning of the information sheet on microcomputers and microprocessor systems.

11. Microcomputer

12. ROM, EPROM, or PROM

13. Keyboard, LED display, printer, teletype, etc.

14. 16-bit

15. Direct memory access

PROGRAM: ELECTRONICS

TASK: MICROCOMPUTER AND MICROPROCESSING SYSTEMS

TASK # F1-1.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________

EVALUATION SITE ____________

EVALUATOR'S NAME ____________________

PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ____________

TERMINAL PERFORMANCE OBJECTIVE:

Describe the operation of microcomputer and microprocessor systems.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

MICROPROCESSING

F1-1.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required date recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

STUDENT'S SCORE _____

MICROCOMPUTER AND MICROPROCESSOR SYSTEMS

EXAM F1-1.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on microcomputer and microprocessor systems. Each of the statements is true or false. Place the letter associated with the correct answer (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F1-1.4

1. The power of a microprocessor is often measured by its instruction set.

   A. True
   B. False

2. Machine language is the most basic of all programming languages.

   A. True
   B. False

3. A microprocessor is a CPU on a chip.

   A. True
   B. False

4. RAM is short for read any memory.

   A. True
   B. False

5. The instruction register holds the present instruction being examined by the microprocessor.

   A. True
   B. False

6. Assembly language is the "language of the machine."

   A. True
   B. False

7. A subroutine is a group of instructions used more than once in a program.

   A. True
   B. False

8. The stack is an area in memory for temporary data storage.

   A. True
   B. False

9. An interrupt is a method of controlling slow peripherals.

   A. True
   B. False

10. Most often, hardware can be grouped into seven categories.

    A. True
    B. False

EXAM KEY F1-1.4

1. A
2. A
4. B
5. A
6. B
7. A
8. A
9. B
10. A

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (8085)

F1-2: MICROCOMPUTER BUS STRUCTURE

TASK:	Diagram and define the bus structure of a microprocessor.
PURPOSE:	The bus structure consists of the interconnecting wires used by microprocessors to communicate with memory and peripheral devices, carrying data, addresses, and controls. In this guide you will learn some of the terminology used to discuss bus structure; also you will gain experience with some of bus interconnect devices.
OBJECTIVE:	Given a written exam, you will diagram and define the bus structure of a microprocessor. To master this task you must score 80% on a written exam.

ESTIMATED CLASS TIME: 5 HOURS

MICROCOMPUTER BUS STRUCTURES

LEARNING STEPS

F1-2

READ: Information sheet F1-2.1 on "Microcomputer Bus Structures."

READ: Information on microcomputer bus structures from the following resource list.

COMPLETE: Activity sheet F1-2.2 on "Microcomputer Bus Structures."

COMPLETE: Performance Checklist F1-2.3. Contact your instructor.

REVIEW: All material listed in this learning guide.

COMPLETE: Written exam F1-2.4. Contact your instructor.

MICROCOMPUTER BUS STRUCTURES

RESOURCES

F1-2

1. MCS-80/85 FAMILY USERS MANUAL (Intel, 1979).
2. Zumchak, MICROCOMPUTER DESIGN AND TROUBLESHOOTING (Howard Sams, 1982).
3. Leventhal & Walsh, MICROCOMPUTER EXPERIMENTATION WITH THE INTEL SDK 85 (Prentice Hall, 1980).
4. Hall, MICROPROCESSOR AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Edition.
5. Bery, MICROPROCESSOR AND HARDWARE INTERFACING & APPLICATIONS (Merrill, 1984).
6. PERIPHERAL DESIGN HANDBOOK (Intel, 1981).
7. Goody, THE INTELLIGENT MICROCOMPUTER (SRA, 1982).
8. Larsen, Titus, & Titus, 8085A COOKBOOK (Howard Sams, 1982).
9. Titus, Rony, Larsen & Titus, 8080/8085 SOFTWARE DESIGN BOOK I (Howard Sams, 1982).
10. Larsen, Titus, & Titus, 8080/8085 SOFTWARE DESIGN BOOK II (Howard Sams, 1981).

INFORMATION SHEET

F1-2.1

MICROCOMPUTER BUS STRUCTURES

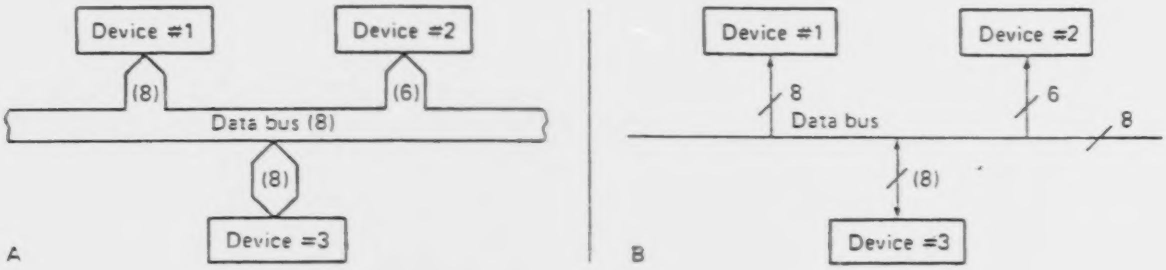
A bus may be defined as a pair or a group of wires in which each wire carries the same type of information as any other wire in the group. A bus is a way of providing connections between the inputs and outputs of a number of circuits. A bus allows the various elements of a system to communicate, that is, to send digital information back and forth.

The devices connected to a bus can be transmitters or receivers; they can send or they can receive information. In a microprocessor system, the CPU determines which devices are transmitters and which are receivers at any given time, by addressing the device at the same time a control line signals the device to transmit or to receive.

Buses may be shown schematically in a variety of ways; for example, Figure F1-2.1-1 shows two diagrams of typical 8-bit bused systems. The two systems are equivalent, and you may find either in equipment manuals and service diagrams.

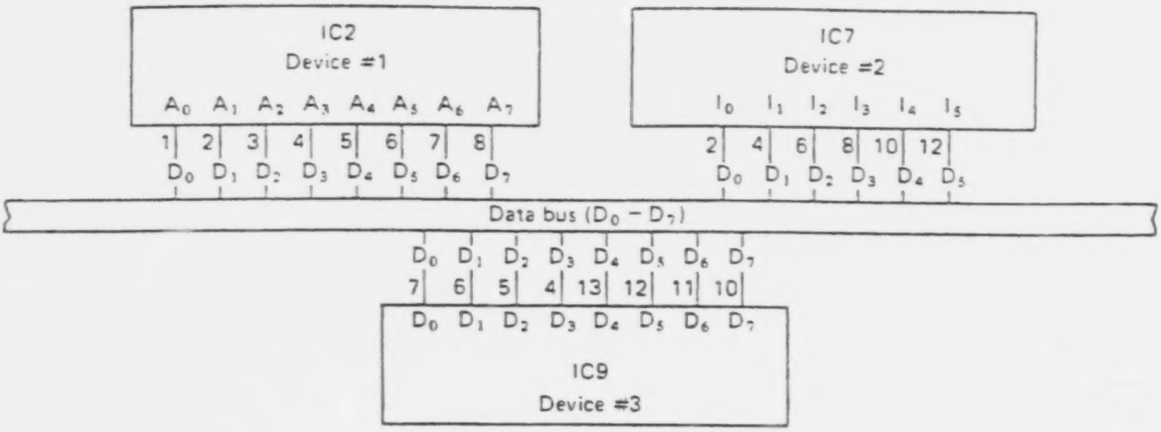
Normally, such diagrams include the bus name, the number of wires in the bus, and the direction of information flow. However, if you examine Figure F1-2.1-1A you will see the number of wires in the bus in brackets, where Figure F1-2.1-1B shows the number of wires next to the slash mark. Both of these diagrams show six wires breaking off from the bus and connect to device number two.

Figure F1-2.1-1:



A schematic diagram for the system shown in F1-2.1-1 is shown in F1-2.1-2. Notice the bus is still shown as if it were a single wire, but more information is shown in a schematic than on a block diagram. Usually, each wire is identified and its destination is clearly shown.

Figure F1-2.1-2:


IC2
Device #1
A0 A1 A2 A3 A4 A5 A6 A7
1 2 3 4 5 6 7 8
D0 D1 D2 D3 D4 D5 D6 D7
IC7
Device #2
I0 I1 I2 I3 I4 I5
2 4 6 8 10 12
D0 D1 D2 D3 D4 D5
Data bus (D0 – D7)
D0 D1 D2 D3 D4 D5 D6 D7
7 6 5 4 13 12 11 10
D0 D1 D2 D3 D4 D5 D6 D7
IC9
Device #3

There are three types of buses in a microprocessor system. They are: CPU internal buses, I/O buses, and microcomputer buses.

CPU buses are used to carry information between the various sections of a CPU and are confined within the microprocessor itself. An in/out bus is a set of wires over which a microcomputer communicates with its peripherals. These buses allow the processor to control processes, read monitoring devices, and send data to other devices. A microcomputer bus is a set of wires which carries information between the CPU and other major components within the system.

Microcomputers are constructed on one or more printed circuit boards, each of which has a specific function or set of functions. The circuit boards are connected to each other or to other parts of the system by plugging them into a motherboard or backplane.

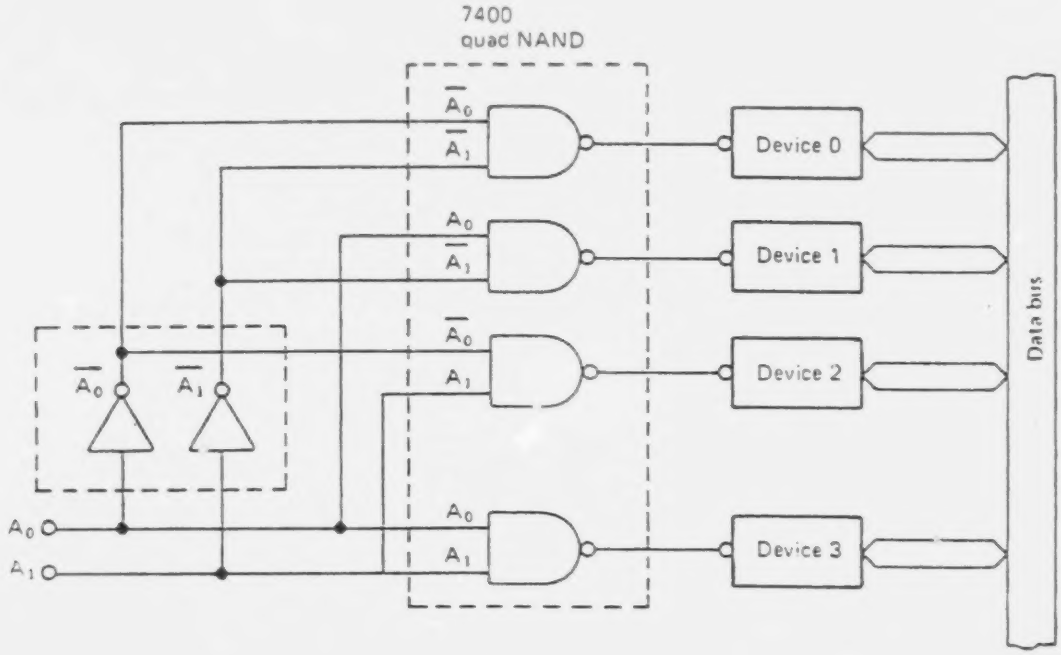
Backplanes usually contain a number of printed circuit sockets, which are mounted in a frame and wired together. Each microcomputer system has its own set of connections between printed circuit boards. But all backplanes have some type of bus structure that has elements in common with other bus structures.

The logic levels and voltage levels for signals on a given bus are specified. If a PC card is to work with a particular bus, the bus must be able to send and receive signals at that level.

All microcomputer buses have common functional groups for data, address, and control. The data bus might carry instructions from memory to the CPU, data from memory or and input device to the CPU, and data transferred from CPU or memory to output. Data bus lines are typically labeled D0 through D7, where D0 is the least significant bit, (LSB) and D7 is the most significant bit, (MSB).

When the CPU wants data from a device on the bus, it selects the device by sending the device address out on the address bus. Each device on the address bus has a decoder associated with it. Every device on the bus sees each address as it is sent out. Only the device whose address matches the one on the bus responds by outputting its data on the data bus. Figure 3 illustrates a simple address decoder for a 2-bit address bus. A typical address bus for an 8-bit machine is 16 bits, which means 65,536 unique addresses. This is usually referred to as 64K of memory.

Figure F1-2.1-3:


7400
quad NAND
$\overline{A}_0$
$\overline{A}_1$
A_0
$\overline{A}_1$
$\overline{A}_0$
A_1
A_0
A_1
$\overline{A}_0$
$\overline{A}_1$
A_0
A_1
Device 0
Device 1
Device 2
Device 3
Data bus

As you know, the data bus transfers data between devices, while the address bus determines which devices are to send or receive information. The control bus tells the addressed device what to do with the data and when to do it.

Each microprocessor has its own unique set of control lines, which will vary with individual design and the choice of devices connected to it. However, there are some lines which are found on almost all designs and microprocessors. These would be as follows: read/write, system clock, system reset, address valid, and I/O memory.

The read/write lines in a control bus enable the CPU to tell devices on the bus either to receive data from the data bus (read) or to output data to the data bus (write). The read/write information may be transferred on the same line by varying the logic or there may be two separate lines.

Microprocessor systems are synchronous; everything is controlled by system clock. Without the system clock, the processor would have devices trying to use the buses at the same time and data would be crashing into other data.

A system reset is used to reset the microprocessor to a predefined condition. It will reset the program counter to zero or some selected value. It clears the subroutine stack and generally readies the CPU to begin executing its program from the start. This control is often used to gain control over a program which has entered a loop, and is said to be in a runaway condition.

An address-valid, sometimes called address-enable, is used to signal that the address on the address bus is valid. This is necessary because the address lines do not all change at exactly the same time. There is also the case where address lines carry information other than addresses. An example is where the address lines might share data between memory and I/O devices. The address-valid line effectively prevents false address decoding by the microprocessor.

The in/out memory control line is a control shared by two separate functions. Usually the line is at a logic low to indicate it is doing the memory control function; that is, when it is low there will be a read or write from memory, not from an in/out device.

These are a few of the more common control line examples. Each processor will have control lines which are unique to its architecture. The best explanation of the control lines for the processor you are using is to investigate a user's manual for that particular microprocessor.

Devices which tie to the bus have to be buffered, electronically disconnected when not in use, and sometimes multiplexed to share space on the bus. Multiplexing is a method of allowing several signals to share the same wire or bus. Most processors use a method called time-division multiplexing.

The microprocessor itself is usually not capable of driving a large current load; usually it can drive one or two LS-TTL loads. This means that driver chips will usually have to be put on the bus between the processor and the device sending or receiving data. Drivers can be of various types according to the job they have to perform. A driver may be classified as an uni-directional device, meaning it can only handle data in one direction, or it may be a bi-directional device capable of handling data in either of two directions. Most drivers are classified as tri-state devices, meaning they have three logic states: high, low, and off, electrically disconnected from the bus.

There is no one industry standard when it comes to bus structure; however, there are several buses which are used quite commonly by the industry. The S-100 bus was originally developed for personal computers, but has now been adopted by the IEEE (Institute of Electrical and Electronic Engineers) as Standard IEEE-696. The S-100 bus has 100 pin connections, which means it is a rather large bus. The printed circuit cards are usually about 10 inches by 5 inches, which allows for fairly involved circuit card design.

Another popular bus is the Multibus, which was developed by Intel Corp. for its 8080 single board microcomputer. The Multibus has been upgraded to handle 16-bit processors and has 24-bit address bus which will accommodate a full 16 megabytes of memory. The Multibus board size is approximately 12 inches by 6.75 inches, and is Standard IEEE-796.

One other popular bus is the STD bus, which was developed by Pro-Log and Mostek Corporation. This bus is aimed at industrial and process control applications. The bus card is relatively small measuring approximately 6.5 inches by 4.5 inches. These boards carry only a few functions, so they are cost effective and easily designed.

As you can see after reading this learning guide, there is more to a bus than a group of wires. There are several bus standards, there are bus support chips, and there are particular functions for each wire in the bus. It should also be apparent that the concept of a bus allows the user to easily tie many circuit boards together without hundreds of wires and interconnects.

ACTIVITY SHEET

F1-2.2

MICROCOMPUTER BUS STRUCTURES

Fill in the blank for the statements listed below:

1. A pair or group of wires connecting circuit inputs and outputs is called a signal __________________.
2. What portion of a computer determines whether the devices connected to a bus will transmit or receive? ____________
3. The CPU bus is confined within the ______________ chip.
4. The set of wires over which a microcomputer communicates with external devices is called a(n) ______________ bus.
5. In a microcomputer, circuit boards are connected to each other and to the system by plugging them into a(n) ________________.
6. When the CPU wants to get data from a device on the bus, it sends the device's __________________ out on the ______________ bus.
7. What function of a control bus tells devices to receive or output data? _________________
8. Signals from the system clock regulate the microprocessor system, making it a(n) _________________ system.
9. The method that allows several signals to share a computer bus at once is called time-division _____________ system.
10. In electronics, a driver circuit supplies the ___________ to another circuit.
11. The output states of a three-state bus driver are ______________, ______________, and ______________.
12. Give two common names for the control lines on tri-state chips. ________________ and ________________
13. The largest and most complex of the standard buses is the _________________ bus.

ACTIVITY SHEET F1-2.2

ANSWER SHEET

1. bus
2. the CPU
3. microprocessor
4. I/O
5. backplane
6. address address
7. read/write
8. synchronous
9. multiplexing
10. input
11. high low off
12. output enable chip select
13. S-100

PROGRAM: ELECTRONICS

TASK: MICROCOMPUTER BUS STRUCTURES

TASK # F1-2.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ___________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Diagram and define the bus structure of a microprocessor.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

MICROCOMPUTER BUS STRUCTURES

F1-2.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required date recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

STUDENT'S SCORE _____

MICROCOMPUTER BUS STRUCTURES

EXAM F1-2.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on microcomputer bus structures. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F1-2.4

1. A pair or group of wires which provide connections between the inputs and outputs of a number of circuits is called a ________.

   A. bus
   B. cable
   C. PC board
   D. modem

2. Which of the following is NOT one of the three distinct types of buses in a microprocessor system?

   A. CPU internal buses
   B. I/O buses
   C. microcomputer buses
   D. external buses

3. You can connect printed circuit boards to each other by plugging them into a ________.

   A. common pinout
   B. backplane
   C. mainframe
   D. card cage

4. The three common bus functions of a microprocessor system are ________.

   A. data, address, and I/O
   B. data, address, and control
   C. control, I/O, and interface
   D. data, address, and interface

5. Which of the following carries instructions from the program memory to the CPU?

   A. address bus
   B. I/O bus
   C. data bus
   D. control bus

6. When the output-enable control line of a device is held _______________, the device output is __________________.

   A. low, on
   B. low, off
   C. high, on
   D. high, undefined

7. Which of the following buses tells the selected device what to do with data and when to do it?

   A. I/O bus
   B. control bus
   C. data bus
   D. address bus

8. Which of the following is not a common type of bus driver found in a microprocessor system?

   A. bi-directional driver
   B. three-state driver
   C. open-collector driver
   D. multiplexed driver

9. Which of the following is not a bus standard specification?

   A. signal pinouts
   B. drive capability
   C. manufacturer's name
   D. PC board size and shape

10. Which of the following industry standard buses is used most often in industrial applications?

   A. STD bus
   B. multibus
   C. S-100
   D. IEEE-796

EXAM KEY F1-2.4

1. A
2. D
3. B
4. B
5. C
6. A
7. B
8. D
9. C
10. A

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (8085)

F1-3: MACHINE LANGUAGE PROGRAMMING

TASK:	Enter, verify, and run a machine language program.
PURPOSE:	The purpose of this learning guide is to acquaint you with a microprocessor trainer, with which you can enter a simple program, verify that you entered it correctly, and run it. After you complete this learning guide, you should easily be able to operate your microprocessor trainer.
OBJECTIVE:	Given access to all necessary tools, equipment, and reference material, you will enter, verify, and run a machine language program. To master this task you must score 80% on a performance checklist.

ESTIMATED CLASS TIME: 5 HOURS

MACHINE LANGUAGE PROGRAMMING

LEARNING STEPS

F1-3

READ: Information sheet F1-3.1 on "Introduction to the Trainer."

READ: Information on microprocessor trainers in one or more resources listed below.

COMPLETE: Activity sheet F1-3.2 on "Introduction to the Trainer," and F1-3.3 on "Simple Machine Programs."

COMPLETE: Lab performance on the microprocessor trainer. Contact your instructor.

PRACTICE: Entering, verifying, and running programs on your trainer.

COMPLETE: Performance checklist F1-3.4. Contact your instructor.

MACHINE LANGUAGE PROGRAMMING

RESOURCES

F1-3

1. MCS-80/85 FAMILY USERS MANUAL (Intel, 1979).
2. Zumchak, MICROCOMPUTER DESIGN AND TROUBLESHOOTING (Howard Sams, 1982).
3. Leventhal & Walsh, MICROCOMPUTER EXPERIMENTATION WITH THE INTEL SDK 85 (Prentice Hall, 1980).
4. Hall, MICROPROCESSOR AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Edition.
5. Bery, MICROPROCESSOR AND HARDWARE INTERFACING & APPLICATIONS (Merrill, 1984).
6. PERIPHERAL DESIGN HANDBOOK (Intel, 1981).
7. Goody, THE INTELLIGENT MICROCOMPUTER (SRA, 1982).
8. Larsen, Titus, & Titus, 8085A COOKBOOK (Howard Sams, 1982).
9. Titus, Rony, Larsen & Titus, 8080/8085 SOFTWARE DESIGN BOOK I (Howard Sams, 1982).
10. Larsen, Titus, & Titus, 8080/8085 SOFTWARE DESIGN BOOK II (Howard Sams, 1981).

INFORMATION SHEET

F1-3.1

INTRODUCTION TO THE TRAINER

In order to study microprocessors you will have to have access to some sort of microprocessor trainer, which may be a home built unit or one purchased from a company. The system will probably consist of a microprocessor chip, RAM, ROM, support chips, a display, hex keypad, and miscellaneous discrete devices. The key to this system will be the monitor program which is burnt in ROM. It is this device that gives the system its "smarts." It will be very advantageous for you to read the operation manual for your system from cover to cover. The more information you have about your system the easier it will be for you to use it, and use it effectively.

Your microprocessor trainer will have some form of data entry, usually in the form of a 20-plus keypad. Some of the keys will be special function keys, while the rest will be hexadecimal numbered.

One key you will probably see is the reset key. This key is used to reset the system after it has been plugged in or in case a program gets into what is called a "loop."

There should be a key which will allow you to enter your program into memory. This key is sometimes labeled mem.sub. It will allow you to specify a place in existing memory where you can load your program or programs. You will have to refer to your user's manual to find the area in memory which the system has set aside for program use.

Another key marked single step is used to allow you to step one instruction at a time through your program. This function is very helpful when your program doesn't work and you need to see at what point it quits working. Without this function you would never be able to slow the processor down to see what is taking place in the program.

Used in conjunction with the single step key the substitute memory key, will cause the processor to increment one step or one place at a time.

To point your system to a place in memory where a program starts there is a key marked GO. You will press it and then load a memory location into the system. Usually you will press the execution key after this and your program will run. After the program has completed its duty, the display will indicate some sort of prompt to tell you the program has finished.

A very useful key is the key marked exam. reg., for with this key you can very quickly examine any of the registers inside the microprocessor. This key will allow you to examine very easily the accumulator to see if the result of some operation is what you thought it should have been.

The rest of the keys will probably be hexadecimal keys, which allow you to enter the data in hex rather than binary. As a matter of fact, all of your communication with the processor will be by hexadecimal numbers. You will use hex for data as well as for memory specification.

This is by no means all the information you will need about your system; that is what the operation manual is for. Use this manual; it has a wealth of information. It probably also has a monitor listing in the back, which is a listing of all the machine code used by the processor. These little programs which go together to form the monitor can be used in your programs. If you start to use these, you will save yourself much time.

One last thing before closing, do not get discouraged by machine language programming. It is a skill that will come to you if you try hard enough. PRACTICE, PRACTICE, PRACTICE.

ACTIVITY SHEET

F1-3.2

INTRODUCTION TO THE TRAINER

DIRECTIONS:

On a separate piece of paper complete the activities listed below:

1. Draw a functional block diagram of your microprocessor trainer. (Refer to the user's manual.)

2. Give the memory location in RAM where you may load your programs. ____________________ to ____________________.

3. List some of the subroutines in your monitor, and their memory location in ROM.

____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________

4. The ____________________ key can be used if your program enters a loop.

5. ____________________ is the key to press to start or run your program.

6. ____________________ key would be used if you wanted to see what was the accumulator.

ACTIVITY SHEET F1-3.2 CONT'D.

7. To examine your program one line at a time you would use the ____________________ key.

8. Give the procedure required to load a simple program into memory, verify it, and run the program.

9. Draw a simple coding sheet that you might use to list or show the following information:

   A. Memory location

   B. Mnemonic

   C. Machine code

   D. Comments

ACTIVITY SHEET F1-3.2

ANSWER SHEET

1. Diagram will depend on the trainer used.

2. Again, it will depend of the trainer. Might be 20000H to 20FFH.

3. Check monitor listing: console input-07FD; console output 07FA; UPDAD-0363; UPDDT-036E; RDKBD-02E7; DELAY-05F1; OUTPT-02B7.

4. Reset key

5. Execute

6. Exam. reg.

7. Single step

8. Reset the microprocessor, and push the exam.reg. key and load the starting address. At the first location in memory place your first instruction of the program. Push the "next" key and load the second step of the program. Continue this procedure until until all of the program is loaded. To verify the program press the sub. memory key load address of first memory location, then press the "next" key to check if the correct code was entered. Continue this until all of your program code has been verified. To run the program press the GO key, and enter the starting address for the program you just entered and verified. The last key to push is the exec.key. Your program should run.

```
   MEMORY
ADR. DATA      MNEMONIC                  COMMENTS
2000 3D1A      MVI A,1Ah                 ;Move 1AH into the accum.
2002 060A      MVI B,0Ah                 ;Move 0AH into the B reg.
2004 90        SUB B                     ;Subtract reg. B from accum.
2005 76        HLT                       ;Halt the program. stop
```

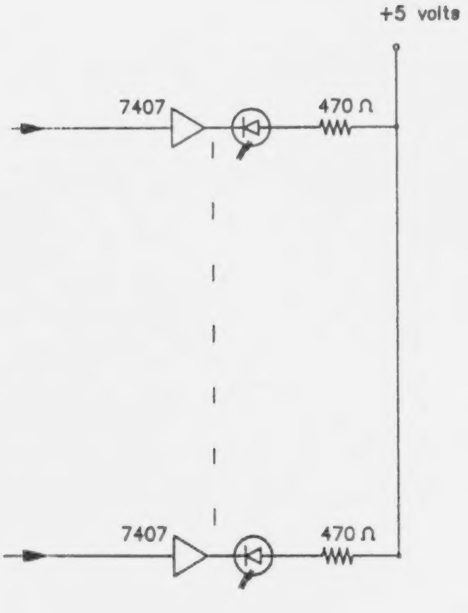
This type of chart makes entering and troubleshooting long programs much easier.

ACTIVITY SHEET F1-3.3

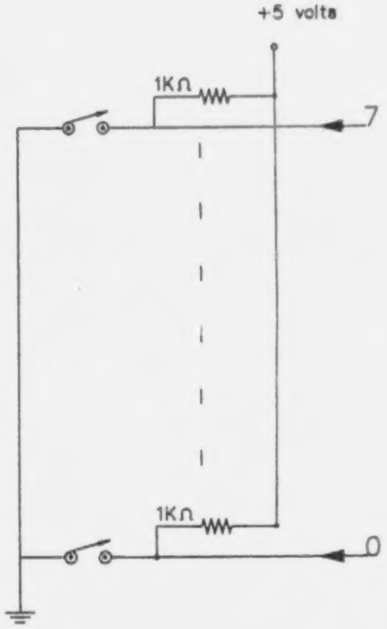
SIMPLE MACHINE LANGUAGE PROGRAMS

DIRECTIONS: On a separate piece of paper complete the activities listed below.

1. Write and run a program which calculates the two's complement of memory location 2042H and stores the result in memory location 2043H. Hint: Remember two's complement is one's complement plus one.
2. Write and run a program which inputs data from a port (21) and saves it in register B.
3. Write and run a program which will input three successive bytes of data from a port (21), store it in three different registers, and then output the three data bytes to a port (22) in reverse order.
4. Write and run a program which moves data from a port (21) to memory location 2040H.
5. Write and run a program which adds the contents of memory locations 2040H and 2041H and places the result in memory location 2042H.



OUTPUT PORT 22



INPUT PORT 21

ACTIVITY SHEET F1-3.3

ANSWER SHEET

1.

```
ADDRESS         INSTRUCTION               COMMENTS
(HEX)           (MNEMONIC)
-----------------------------------------------------------------
2000            LDA   2042H               ; Get the data
                CMA                       ; One's complement
                INR   A                   ; Two's complement
                STA   2043H               ; Store results
                RST   1                   ; Stop with reg. intact
-----------------------------------------------------------------

PROGRAM 2.
2000H           MVI   A,OE                ;Initialize the 8155 chip
                OUT   20H                 ;To command status reg.
                IN    21H                 ;Input data from port 21
                MOV   B,A                 ;Save data in reg. B
                HLT                       ;Stops reg. content gone
-----------------------------------------------------------------

PROGRAM 3.
2000H           MVI   A,OE                ;Initialize the 8155
                OUT   20H                 ;To command status reg.
                IN    21H                 ;Input data from port 21H
                MOV   B,A                 ;Save value in reg. B
                IN    21H                 ;Input again from 21
                MOV   C,A                 ;Save in reg. C this time
                IN    21H                 ;In again from port 21
                OUT   22H                 ;Output reg. A to port 22
                MOV   A,C                 ;Get contents from C
                OUT   22H                 ;Output C's content
                MOV   A,B                 ;Move B';s content
                OUT   22H                 ;Out B to port 22H
                HLT                       ;Stop
-----------------------------------------------------------------

PROGRAM 4.
2000H           MVI   A,OE                ;Initialize the 8155 chip
                OUT   20H                 ;To command status reg.
                IN    21H                 ;Move data from A to mem.
                STA   2040H               ;Store accum in memory
                RST   1                   ;Break point reg. can be
                                           examined.
-----------------------------------------------------------------
```

ACTIVITY SHEET F1-3.3 CONT'D.

PROGRAM 5.

```
2000            LXI  H,2040H            ;Set the pointer
                MOV  A,M                ;Get first operand
                INX  H                  ;Advance pointer
                ADD  M                  ;Add second operand
                INX  H                  ;Advance memory pointer
                MOV  M,A                ;Store result
                RST  1                  ;Go back to monitor
```

NOTE: This program presumes you have data in memory locations 2040 AND 2041.

PROGRAM: ELECTRONICS

TASK: MACHINE LANGUAGE PROGRAMMING

TASK # F1-3.4

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Enter, verify, and run a machine language program.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 8 out of 10 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 8 out of 10 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

MACHINE LANGUAGE PROGRAMMING

F1-3.4

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required date recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the no column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

STUDENT'S SCORE ______

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (8085)

F1-4: MICROPROCESSOR ARCHITECTURE

TASK:	Diagram and define the architecture of a microprocessor.
PURPOSE:	The architecture of a microprocessor refers to its internal structure. This learning guide will introduce you to the architecture of a popular 8-bit microprocessor, the 8085. After you complete this learning guide, you should have a pretty good understanding of what is inside a microprocessor chip and how each part functions.
OBJECTIVE:	Given a written exam, you will diagram and define the architecture of a microprocessor. To master this task you must score 80% on a written exam.

ESTIMATED CLASS TIME: 5 HOURS

MICROPROCESSOR ARCHITECTURE

LEARNING STEPS

F1-4

READ:	Information sheet F1-4.1 on "Microprocessor Architecture."
READ:	Information on microprocessor architecture in one or more resources listed below.
COMPLETE:	Activity Sheet F1-4.2 on "Microprocessor Architecture."
COMPLETE:	Lab performance of microprocessor architecture. Contact your instructor.
COMPLETE:	A review of all materials covered by this learning guide.
COMPLETE:	Performance Checklist F1-4.3. Contact your instructor.
COMPLETE:	Written exam F1-4.4. Contact your instructor.

MICROPROCESSOR ARCHITECTURE

RESOURCES

F1-4

1. MCS-80/85 FAMILY USERS MANUAL (Intel, 1979).
2. Zumchak, MICROCOMPUTER DESIGN AND TROUBLESHOOTING (Howard Sams, 1982).
3. Leventhal & Walsh, MICROCOMPUTER EXPERIMENTATION WITH THE INTEL SDK 85 (Prentice Hall, 1980).
4. Hall, MICROPROCESSOR AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Edition.
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6. PERIPHERAL DESIGN HANDBOOK (Intel, 1981).
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8. Larsen, Titus, & Titus, 8085A COOKBOOK (Howard Sams, 1982).
9. Titus, Rony, Larsen & Titus, 8080/8085 SOFTWARE DESIGN BOOK I (Howard Sams, 1982).
10. Larsen, Titus, & Titus, 8080/8085 SOFTWARE DESIGN BOOK II (Howard Sams, 1981).

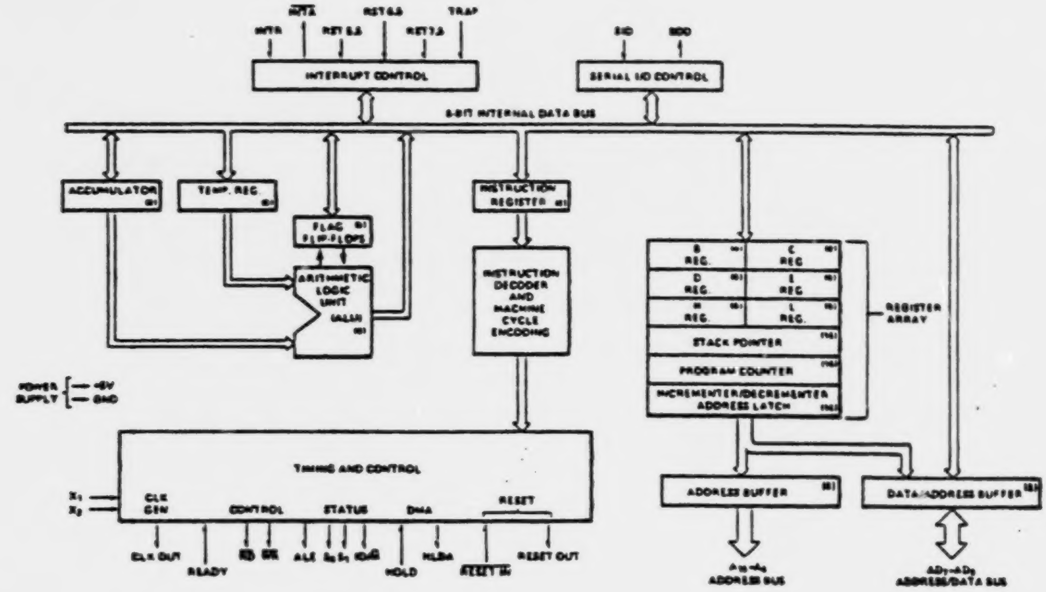
INFORMATION SHEET

F1-4.1

MICROPROCESSOR ARCHITECTURE

Figure F1-4.1-1 is an example of the architecture of an 8-bit microprocessor. Each section of the processor is drawn in block form; the external connections are also shown and labeled.

Figure F1-4.1-1:


INTA
RST 6.5
TRAP
INTR
RST 5.5
RST 7.5
SID
SOD
INTERRUPT CONTROL
SERIAL I/O CONTROL
8-BIT INTERNAL DATA BUS
ACCUMULATOR (8)
TEMP. REG. (8)
FLAG (5) FLIP-FLOPS
ARITHMETIC LOGIC UNIT (ALU) (8)
INSTRUCTION REGISTER (8)
INSTRUCTION DECODER AND MACHINE CYCLE ENCODING
B REG. (8)
C REG. (8)
D REG. (8)
E REG. (8)
H REG. (8)
L REG. (8)
STACK POINTER (16)
PROGRAM COUNTER (16)
INCREMENTER/DECREMENTER ADDRESS LATCH (16)
REGISTER ARRAY
POWER SUPPLY
+5V
GND
TIMING AND CONTROL
X1
X2
CLK GEN
CONTROL
STATUS
DMA
RESET
CLK OUT
READY
RD
WR
ALE
S0
S1
IO/M
HOLD
HLDA
RESET IN
RESET OUT
ADDRESS BUFFER (8)
DATA/ADDRESS BUFFER (8)
A15-A8 ADDRESS BUS
AD7-AD0 ADDRESS/DATA BUS

A8 through A15 are high-order address lines, connected to the address bus and connected internally to a tri-state address buffer. Above the address buffer is an address latch, used as a pointer to indicate the next memory location. This latch is a 16-bit device which also feeds the data/address buffer.

The low-order address is shared by the data bus. This is an example of a multiplexed bus, which is required to keep the number of external pins to a minimum. Note the double-ended arrows on the internal bus feeding the data/address buffer; this is the internal data bus which is a bi-directional bus.

Above the address bus latch is the program counter, which keeps track of what instruction is to be executed next. The program counter is a 16-bit register, capable of a program count of 64K.

The stack pointer is another special 16-bit register, used to hold the current place in the program when a subroutine is called. The stack can also be used as a temporary 16-bit register by using instructions to "push" information on the stack. The stack is a "last-in-first-out" type of data structure.

Near the 16-bit special registers there are six general purpose 8-bits registers labeled b, c, d, e, h, and l.

These registers can be used in pairs to hold 16-bit data; however, the b and c register must be used together, also the d and e, and the h and l. The h and l registers are often used as a memory pointer when using data transfer instructions.

The large block labeled timing and control, controls the timing and sequencing which is necessary to execute each instruction.

The instruction register is an 8-bit register used to hold the instruction which has just been received from the data bus. When the time is right the instruction will be passed to the decoder where it will be decoded and the necessary machine cycles encoded for processing by the timing and control block.

All of the logic and arithmetic operations will be performed by the ALU. It receives its data from the accumulator and an 8-bit temporary register. The flag register is located next to the ALU to flag conditions of the process performed by the ALU. The flag registers set the zero flag, carry flag, sign flag, and parity flag. You will learn how these flags are used when you get into some programming using jump or branch instructions.

The accumulator is a register, but it is special in that all data fed to the ALU will come through this register. It is used to hold all of the results from an arithmetic or logic operation.

All interrupts are received and controlled by the interrupt control block. An interrupt is a signal to the processor, usually from a slower peripheral device that it needs the microprocessor's attention. The processor will signal the external device it has received its interrupt by dropping the interrupt acknowledge line low. There are several types of interrupts available on this processor, and their function will be best explained by reading a user's manual.

INFORMATION SHEET F1-4.1 CONT'D.

Serial data transfer is provided by this processor through the serial I/O control block. Connected to this area of the chip are two pins marked SID and SOD which are used for serial data in and serial data out. They allow the microprocessor to receive serial data from and external source and process it internally as parallel data and send it back out as serial data.

At this point, we have looked at the internal sections of the microprocessor, the architecture; now we will need to look at some of the control lines. Their function is important to the operation of the processor. X1 and X2 are connected to a crystal, LC, or RC network to drive the internal clock generator.

A product of these inputs is the CLK output, which is a clock output for use as a system clock. The period of this output is twice the X1 and X2 input period.

From here we move to the ready input; you can tell this is an input by the direction of the arrow on the line. If ready is high during a read or write cycle, it indicates that the memory or peripheral is ready to send or receive data. If ready is low, the CPU will wait an integral number of clock cycles for ready to go high before completing a read or write cycle.

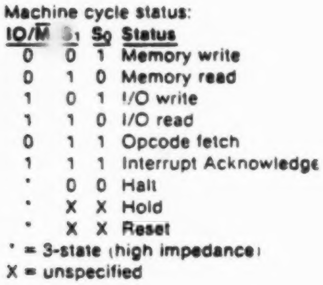
The read output is a low-active output as indicated by the bar. This output is used to signal that the selected I/O or memory device is to read, and the data bus is available for data transfer. It is a tri-state device, which is tri-stated during hold, halt, and reset operations.

Write control is a low-active tri-stated output signal, used to indicate that the data on the data bus is to be written to a selected I/O or memory device. Data will be set up for transfer during the trailing edge of WR. It will be tri-stated during hold, halt, and reset operations.

ALE is short for address latch enable, and does what its name implies; it enables the address information to be latched on the address bus. The signal will be present during the first clock state of a machine cycle, and is high-active. The falling edge of the ALE can be used to strobe status information.

Status information is a sneak preview of operations yet to occur. It can be latched and used as external control. Status information is used in conjunction with the I/O memory line as advanced operations information. Figure F1-4.1-2 is an example of status information.

INFORMATION SHEET F1-4.1 CONT'D.



Machine cycle status:

IO/$\overline{M}$	S_1	S_0	Status
0	0	1	Memory write
0	1	0	Memory read
1	0	1	I/O write
1	1	0	I/O read
0	1	1	Opcode fetch
1	1	1	Interrupt Acknowledge
*	0	0	Halt
*	X	X	Hold
*	X	X	Reset

* = 3-state (high impedance)
X = unspecified

Figure F1-4.1-2

Upon receiving a hold request, which is a signal that another master is requesting the use of the address and data buses, the CPU will relinquish the use of the bus as soon as it completes the current bus transfer. The processor can regain the bus only after the hold is removed. When a hold is received and acknowledged, the address, data, read, write, and I/O memory lines are tri-stated. The CPU signals it has received a hold request by sending the hold acknowledge, HLDA, line low.

There are two resets on most microprocessors; one is an input and the other is an output. Reset sets the program counter to zero and resets the interrupt enable and HLDA flip-flops. Reset out is an output signal which has received a hold request by sending the hold acknowledge HLDA line low.

Finally, two inputs without which the processor could not operate are power and ground. There is only one voltage supply required of this processor, and it is a standard plus-5 volts. Older processors required two or more supply voltages, which added cost and complexity to the design.

This concludes the information on the architecture of a microprocessor. It is strongly suggested that you read more and investigate a user's manual for the processor you are going to use.

ACTIVITY SHEET

F1-4.2

MICROPROCESSOR ARCHITECTURE

1. The _______________ receives all data to be used by the ALU.

2. The __________________ register holds the status information of operations by the ALU.

3. The 8085 has ________________ interrupts available.

4. ________________ is a nonmaskable restart interrupt.

5. ________________ is an out to indicate that an interrupt has occurred.

6. SID is short for ______________ ______________ ____________.

7. The internal data bus is a _________________ bus.

8. The low-order address bus shares with the _____________ bus.

9. The low-order address bus is an example of a _______________ bus.

10. The _______________ keeps track of which instruction in the program will be next processed.

11. _______________ is used to strobe status off the bus.

12. The ________________ output is used to latch the low-order address information.

13. ________________ indicates that another master is requesting the use of the address and data buses.

14. An LC or a RC network may be tied to the ________________ inputs.

15. _______________ can be used as a system reset.

ACTIVITY SHEET F1-4.2

ANSWER SHEET

1. accumulator
2. flag
3. five
4. trap
5. INTA
6. serial input data
7. bi-directional
8. data
9. multiplexed
10. program counter
11. ALE
12. ALE
13. hold
14. X1, X2
15. reset out

PROGRAM: ELECTRONICS

TASK: MICROPROCESSOR ARCHITECTURE

TASK # F1-4.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ___________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Diagram and define the architecture of a microprocessor.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

MICROPROCESSOR ARCHITECTURE

F1-4.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required date recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

STUDENT'S SCORE ______

MICROPROCESSOR ARCHITECTURE

EXAM F1-4.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on microprocessor architecture. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F1-4.4

1. The 8085 system architecture employs ______________.

   A. an 8-bit data bus and an 8-bit address bus
   B. an 8-bit data bus and a 16-bit address bus
   C. a 16-bit data and a 16-bit address bus
   D. none of these

2. The ALU output is fed to the ______________.

   A. instruction decoder
   B. internal data bus
   C. instruction register
   D. the interrupt control block

3. The five condition registers (flag flip-flop) are affected by the operations of the ALU.

   A. True
   B. False

4. The program counter (PC) is a 16-bit register that ______________.

   A. counts the number of steps in a program
   B. holds the memory address of the next program word
   C. causes the contents of the ALU to be incremented
   D. none of these

5. The stack pointer (SP) may hold either address information or data information.

   A. True
   B. False

6. The "stack" is ______________.

   A. a group of fifty 8-bit bytes of memory
   B. a group of memory locations selected by the programmer
   C. a 16-bit register located in the register array of the 8085
   D. none of the above

7. When a CPU is "writing," it is ______________.

   A. transferring data from the CPU to some other area in the system
   B. transferring data into the CPU from some other area in the system
   C. taking data in from memory
   D. none of the above

8. The ALU of a microprocessor performs algebraic and logarithmic operation.

   A. True
   B. False

9. The term "architecture" refers to the ______________.

   A. physical construction of a microprocessor
   B. electronic arrangement of the registers, buses, and other sections within the microprocessor

10. The function of the PC is to store ______________.

   A. data for use by the CPU
   B. the address of the location in memory that is currently being accessed
   C. the address of the next program word to be fetched
   D. none of the above

EXAM F1-4.4

1. A
2. B
3. A
4. B
5. B
6. B
7. A
8. A
9. B
10. C

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (8085)

F1-5: ARITHMETIC PROGRAMMING

TASK: Write, enter, verify, and run machine language arithmetic programs.

PURPOSE: The main objective of this learning guide will be to provide you with experience in writing and testing programs using arithmetic. After you complete this guide, you should have an understanding of some of the data transfer and arithmetic instructions, and the ability to write some simple machine language programs.

OBJECTIVE: Given access to all necessary tools, materials, and equipment, you will write, enter, verify, and run machine language arithmetic programs. To master this task you must score 80% on a performance checklist in 40 minutes or less and 80% on a written exam.

ESTIMATED CLASS TIME: 12 HOURS

ARITHMETIC PROGRAMMING

LEARNING STEPS

F1-5

READ: Information sheet F1-5.1 on "Arithmetic and Data Transfer Instructions."

READ: Information on arithmetic and data transfer instruction," from the following resource list.

COMPLETE: Activity sheets F1-5.2 and 5.3 on "Arithmetic and Data Transfer Instructions."

COMPLETE: Lab performance on arithmetic and data transfer instructions. Contact your instructor.

REVIEW: All the material in this learning guide.

COMPLETE: Performance Checklist F1-5.4. Contact your instructor.

COMPLETE: Written Exam F1-5.5. Contact your instructor.

ARITHMETIC PROGRAMMING

RESOURCES

F1-5

1. MCS-80/85 FAMILY USERS MANUAL (Intel, 1979).
2. Zumchak, MICROCOMPUTER DESIGN AND TROUBLESHOOTING (Howard Sams, 1982).
3. Leventhal & Walsh, MICROCOMPUTER EXPERIMENTATION WITH THE INTEL SDK 85 (Prentice Hall, 1980).
4. Hall, MICROPROCESSOR AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Edition.
5. Bery, MICROPROCESSOR AND HARDWARE INTERFACING & APPLICATIONS (Merrill, 1984).
6. PERIPHERAL DESIGN HANDBOOK (Intel, 1981).
7. Goody, THE INTELLIGENT MICROCOMPUTER (SRA, 1982).
8. Larsen, Titus, & Titus, 8085A COOKBOOK (Howard Sams, 1982).
9. Titus, Rony, Larsen & Titus, 8080/8085 SOFTWARE DESIGN BOOK I (Howard Sams, 1982).
10. Larsen, Titus, & Titus, 8080/8085 SOFTWARE DESIGN BOOK II (Howard Sams, 1981).

INFORMATION SHEET

F1-5.1

ARITHMETIC AND DATA TRANSFER INSTRUCTIONS

In order to program the microprocessor using machine language programming, you will need to learn some machine language instructions. As explained in earlier learning guides, some processors have over 100 machine instructions; therefore, it would be wise to learn only a few of these instructions at any one time. There are usually five separate groups of instruction in the microprocessor's instruction set (1) data transfer, (2) arithmetic, (3) logic, (4) branch, (5) stack I/O, and machine control. We are going to look at a few from the arithmetic and data transfer groups.

The first instruction we will look at is the ADD instruction. There are actually several ADD instructions, because there is one for each register. Usually these instructions affect the Zero, Sign, Parity, Carry, and Auxiliary Carry flags. Also, all subtraction operations are performed via two's complement arithmetic and set the carry flag to indicate a borrow and clear it to indicate no borrow. ADD B is an example of an ADD register instruction. What this particular instruction does is as follows: the contents of register B are added to the contents of the accumulator. The machine code for this one-byte instruction is 80.

In the arithmetic group there are also the following subgroups of arithmetic instructions: ADD MEMORY, ADD IMMEDIATE DATA, ADD REGISTER WITH CARRY, ADD MEMORY WITH CARRY, ADD IMMEDIATE DATA WITH CARRY, AND MANY MORE. The best overview of the arithmetic group of instructions is found in a you must microprocessor user's manual. You must familiarize yourself with one of these manuals.

The next group to look at is data transfer used to transfer data from one place in the system to another. More specifically, this group moves data between registers or between memory locations and registers. It includes moves, loads, stores, and exchanges. STA, which stands for Store Accumulator at the address which directly follows, is a 3-byte instruction with the first byte being the machine code (32), and the second and third bytes being the address where the data is stored. Another example of a data transfer instruction is, LXI rp, which is short for load a register pair. You will recall that the processor has general purpose registers, and they can be used in pairs; this instruction allows you to load a pair with data (or, often a memory location address rather than data). Again, to gain a better understanding of these instructions refer to the user's manual.

INFORMATION SHEET F1-5.1 CONT'D.

After you have studied the data transfer and arithmetic instructions completely, you will be ready to start to develop some programs. Program development can be broken up into eight steps, depending on the length and complexity of the program. First, define your problem. Second, design your program. Third, code the program, Fourth, debug the program. Fifth, test the program. Sixth, document the program. Basically, documentation is a written description of your program so that it can be used by others. Seventh, maintain your program to make it better or meet a slight change of function. Finally, extend and re-design to meet a new need. These are the basic stages of program development, and not all will be used; it will primarily depend on program length and complexity.

An example of the development of a simple program might help at this point. Let's say we want a small program to add two numbers which are already in memory at location 2050H and 2051H. Our program has already been defined for us. The next step is to develop a flow chart or simply block it out in simple English statements: (1) load the data at locations 2050 and 2051 (This is necessary because someone has to put the data into the processor, and that someone is you); (2) add the data; (3) store the answer; (4) halt the program.

As you can see, with a simple program it does not take much to create a design; such will not be the case in a more complex program. The third step is to code the statements or flow chart into machine code. It will be wise for you to get some sort of code chart which allows you to quickly look up the machine code for each instruction; these are usually available in the user's manual. Our example program will code up as follows:

```
ADDRESS OPCODE      MNEMONIC      COMMENTS

2000     215020     LXI H,2050h   ;Load address of first word
2003     3601       MVI M,01h     ;Store data in memory
2005     23         INX H         ;Increment pointer to 2nd word
2006     3602       MVI M,02h     ;Store data in memory
2008     2B         DCX H         ;Decrement pointer to 1st word
2009     7E         MOV A,M       ;Load first word into accum.
200A     23         INX H         ;Increment pointer to 2nd word
200B     86         ADD M         ;Add 2nd number to accum.
200C     325A20     STA 205Ah     ;Store result
200F     76         HLT           ;Stop
```

The next step will be to debug the program, which will require us to check the program for logic and entry errors. First, check the mnemonic for the proper code; you will use a coding card for this. A coding card is usually a small card with all the opcode (machine codes) listed by mnemonic. Secondly, you will need to think the logic of your program through. This is nothing more than thinking out loud. You will merely ask yourself if the machine code does what you want it to do. Example: Does loading a register pair with the instruction, LXI H, set a memory pointer? You will continue with this procedure until you are convinced your logic is good. The third step will be to run the program. If the program does what you wanted it to do then you are finished; however, if the program did not run (and that is usually the case), then you will have to debug it until you find your problem. The fourth and, in the case of this program, the final thing to do will be to test your program to make sure that it works more than just one time.

In summary, it should be pointed out that this is by no means the only way to write a program to add two numbers; there are several ways it could be done. Also you should be aware of the fact that this program is very simple and crude. It could be made to work faster and with fewer program steps, if we had used some of the instructions in the set we have not yet covered. One thing you will learn very quickly about programming is that you are only limited by your imagination and willingness to learn.

ACTIVITY SHEET

F1-5.2

ARITHMETIC AND DATA TRANSFER INSTRUCTIONS

On a separate sheet of paper perform the activities called for.

1. List and define all of the data transfer and arithmetic instructions for the processor you are using. (You should use the user's manual.)

2. Write a program to load ten consecutive memory locations starting at 2050 with zero.

3. Write a program using the monitor routines to add two numbers and display the result on the processor trainer. (See the microprocessor's operation manual.)

ACTIVITY SHEET F1-5.2

ANSWER SHEET

1. The list and description of the data transfer instructions and arithmetic instructions will be found in the user's manual. It is important that you have listed all of these instructions. The more aware of the processor's instruction set you become the better programmer you will become.

2. Program might appear like this:

```
ADDRESS OPCODE   MNEMONIC         COMMENTS
2000    215020   LXIH,2050h       ;Load memory pointer
2003     3E00    MVI A,00h        ;Zero accumulator
2005     77      MOV M,A          ;Store zero in memory
2006     23      INX H            ;Advance pointer to next adr.
2007     77      MOV M,A          ;Store zero in memory
2008     23      INX H            ;Advance pointer to next adr.
2009     77      MOV M,A          ;Store zero in memory
200A     23      INX H            ;Advance pointer to next adr.
                 etc.
```

This process would then continue until all ten zeros had been loaded. Later, when we get to branch instructions, you will see how they would make this program a snap.

3. The listing below is an example of what your program might look like; it will depend on your trainer's monitor.

```
200031C220     LXI SP,20C2          ;Set stack pointer to 20C2
2003 3E08      MVI A,08h            ;Unmask code
2005 30        SIM                  ;Unmask interrupts
2006 CDE702    CALL RDKBD           ;Keyboard subroutine
2009 47        MOV B,A              ;Save number in reg. B
200A CDE702    CALL RDKBD           ;Read another key
200D 80        ADD B                ;Add the two numbers
200E CD6E03    CALL UPDDT           ;Call Another subroutine
2011 C30620    JMP                  ;Jump to 1st call
```

If this program seems strange to you, don't worry because it is using instructions we have not covered.

ACTIVITY SHEET

F1-5.3

SIMPLE MACHINE LANGUAGE ARITHMETIC PROGRAMS

DIRECTIONS: On a separate piece of paper complete the activities listed below.

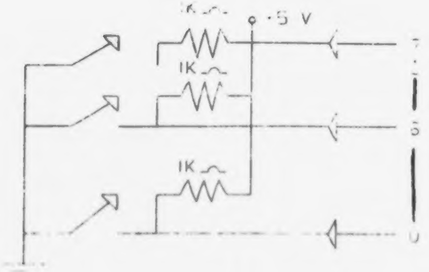
1. Write and run a program which adds two numbers in memory locations 2040H and 2041H and stores the sum in location 2042H. Furthermore, if there is a carry, set the memory location 2043H to 1 and if there is no carry, set the location to zero.

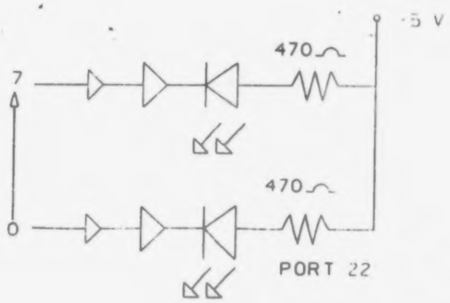
2. Write and run a program which adds an array of 16-bit binary numbers starting in memory location 2043 and places the sum in memory locations 2040 and 2041. Each number is stored in two 8-bit words, with the least significant bits at the lower address. The length of the array (how many 16-bit numbers) is in memory location 2042.

3. Write and run a program which rounds a four-digit BCD number in memory locations 2041 and 2042 (most significant digits in 2042) to a two-digit BCD number in memory location 2040.

4. Write and run a program which uses a look-up table to add squares of the contents of memory locations 2040 and 2041 and places the result in memory locations 2042. Table can be of any length; however, you might want to keep it under 10.

5. Write and run a program which will input a byte from port 21H, adding the most significant half to the least significant half (testing for overflow = error condition) and outputting the result to port 22H.





ACTIVITY SHEET F1-5.3

ANSWER SHEET

```
1.
ADDRESS             INSTRUCTION            COMMENTS
(HEX)               (MNEMONIC)
----------------------------------------------------------------
2000                LXI  H,2040     ;Load your memory pointer
                    MOV  A,M        ;Get first number
                    INX  H          ;Move pointer by one
                    ADD  M          ;Add second number
                    INX  H          ;Move pointer again
                    MOV  M,A        ;Save the sum
                    MVI  A,0        ;Move carry to A
                    ACI  0
                    INX  H          ;Move pointer again
                    MOV  M,A        ;Save carry
                    RST  1          ; Stop and save registers.
----------------------------------------------------------------
PROGRAM 2.
                    LXI  H,2040     ;Set memory pointer
                    MOV  B,M        ;Get array length
                    LXI  D,0        ;Sum=Zero
ADDW:               INX  H          ;Move pointer
                    MOV  A,E        ;Add in 8 LSB'S
                    ADD  M
                    MOV  A,E        ;
                    INX  H
                    MOV  A,D        ;Add in 8 MSB'S
                    ADC  M
                    MOV  D,A
                    DCR  B          ;Decrease your array by 1
                    JNZ  ADDW       ;If not 0 jump to ADDW
                    XCHG            ;Save 16-bit sum
                    SHLD 2040
                    RST  1          ;Stop with reg. saved
----------------------------------------------------------------
PROGRAM 3.
                    LXI  H,2040     ;Set memory pointer
                    MVI  A,49H      ;Set carry if LS digits 50
                    SUB  M          ;
                    INX  H          ;
                    MOV  A,M        ;Add carry to MSD'S
                    ACI  0          ;
                    DAA             ;Make result decimal
                    STA  2040H      ;Save rounded result
                    RST  1          ;Stop with reg. intack
```

(Remember data must be present in 2041 & 2042 before program is run)

ACTIVITY SHEET F1-5.3 CONT'D.

ANSWER SHEET

```
PROGRAM 4.          LXI  D,SQTAB   ;Get base address of table
                    LDA  2040      ;Get first number
                    MOV  L,A       ;Make data into 16-bit index
                    MVI  H,O       ;Get set up for the DAD D
                    DAD  D         ;Access table at proper place
                    MOV  B,M       ;Save square of first number
                    LDA  2041      ;Get second number
                    MOV  L,A       ;Set table pointer again
                    MVI  H,O       ;Get set up for another DAD D
                    DAD  D         ;Access table at proper offset
                    MOV  A,M       ;Get square of second number
                    ADD  B         ;Add squares
                    STA  2042      ;Store sum of squares
                    RST  1         ;Stop with reg. intact
```

NOTE: Table will already be in place at some address you select. The symbolic address is SQTAB. Also, the first and second numbers must be at 2040 and 2041.

Square table would look something like this:

```
                                   MEMORY CONTENT (HEX)
2080   SQTAB:        DB  0         00
                         1         01
                         4         04
                         9         09
                        16         10
                        25         19
                        36         24
                        49         31
                        64         40
                        81         51
                       100         64
-----------------------------------------------------------------
PROGRAM 5.
2000                MVI  A,0       ;Initialize 8155
                    OUT  20H       ;To command reg.
READSW:             IN   21H       ;Read switches port 21
                    MOV  B,A       ;Save a copy of switches
                    ANI  FO        ;Mask off 4 low bits
                    MOV  C,A       ;Save high nibble
                    MOV  B,A       ;Get copy of switches
                    MVI  B,04      ;Initialize loop counter
ROTLEF:             RAL            ;Rotate bit left and
                    ORA  A         ;Clear carry to put bits
                    DCR  B         ;In high nibble
                    JNZ  ROTLEF
                    ADD   C        ;Add saved M.S. nib L.SN
                    JC      ERROR  ;Error sub at your location
                                   Flash display??
```

ACTIVITY SHEET F1-5.3 CONT'D.

ANSWER SHEET

PROGRAM 5 CONT'D.

```
                    MVI  B,04      ;Initialize counter loop
ROTRI:              RAR            ;Rotate result into
                    DCR  B         ;Lower 4 bits
                    JNZ  ROTRI
                    CMA            ;Invert bits
                    OUT  22H       ;Send to LEDS
                    JMP  READSW    ;Do again
```

NOTE: Error subroutine can be of your own design. You might choose to use the monitor output subroutine to flash a message or, you might write your own.

PROGRAM: ELECTRONICS

TASK: ARITHMETIC PROGRAMMING

TASK # F1-5.4

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ___________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Write, enter, verify, and run machine language arithmetic progtams.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation contact your instructor. You must complete your performance within 40 minutes and must score at least 8 out of 10 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 8 out of 10 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

ARITHMETIC PROGRAMMING

F1-5.4

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required date recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

STUDENT'S SCORE ______

ARITHMETIC PROGRAMMING

EXAM F1-5.5

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on arithmetic programming. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F1-5.5

1. The instruction MOV B,A is saying ______________.

   A. move register B to register A
   B. move the contents of register B to register A
   C. move the contents of register A to register B
   D. none of these

2. When a register move instruction is used, the contents of the register are ______________.

   A. lost
   B. remains the same
   C. neither of these

3. To set up a memory pointer you would use ______________.

   A. register pair B and C
   B. register pair D and E
   C. register pair H and L
   D. none of these.

4. The second and third bytes in the instruction STA are ______________.

   A. the data being stored
   B. the location in memory to store the contents of accumulator
   C. neither of these

5. When a register pair is loaded with a memory pointer, the first byte after the opcode is the ______________.

   A. the low-order address
   B. the high-order address
   C. the low-order data
   D. the high-order data

6. If you use the instruction MVI M, you are ______________.

   A. moving memory into the accumulator
   B. moving immediate data to a memory location
   C. moving a memory pointer
   D. moving a memory location

7. The instruction STAX is an instruction which ___________.

   A. stores the contents of the accumulator at a memory location marked by the register pair H and L
   B. stores the contents of the stack at a memory location marked by register pair B and D
   C. stores the contents of the accumulator at a memory location marked by register pair B and D
   D. none of the above

8. SHLD is an instruction used to ___________.

   A. store the contents of a memory location specified in the second and third bytes directly into the H and L register pair
   B. store the contents of the H and L register pair into a memory location specified by the second and third bytes
   C. store the contents of the H and L register pair in the B and C register pair
   D. none of the above

9. The instruction ADD M will ___________.

   A. take the contents of memory and add them to the accumulator
   B. take the contents of a memory location pointed to by H and L reg. pair and add it to the accumulator
   C. add two memory locations together and place answer in the accumulator
   D. none of these

10. The DAD B instruction will ___________.

   A. add the contents of the register pair BC to the contents of the register pair HL and the answer will be placed in the register pair HL
   B. add the contents of the register pair BC to the contents of the register pair D and place the answer in the register pair HL
   C. add the contents of the register pair BC to the contents of the register pair HL and place the answer in the register pair BC
   D. none of the above

EXAM KEY F1-5.5

1. C
2. B
3. C
4. B
5. A
6. B
7. C
8. D
9. B
10. A

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (8085)

F1-6: BRANCHING MACHINE LANGUAGE

TASK: Write, enter, verify and run machine language branching programs.

PURPOSE: This guide introduces you to the branch group of instructions, allowing you to write more complex and powerful programs. After you complete this learning guide, you should have a good understanding of all the branching instructions. You should be able to describe the operation of each. You should also be able to write simple branching programs that use the jump and call instructions.

OBJECTIVE: Given access to all necessary tools, materials, and equipment, you will write, enter, verify, and run machine language branching programs. To master this task you must score 80% on a performance checklist in 40 minutes or less and 80% on a written exam.

ESTIMATED CLASS TIME: 12 HOURS

BRANCHING MACHINE LANGUAGE

LEARNING STEPS

F1-6

READ: Information Sheet F1-6.1, "Branching".

READ: Information on branching from the following resource list.

COMPLETE: Activity Sheet F1-6.2, "Branching," and F1-6.3, "Simple Branching Machine Language Programs".

COMPLETE: Lab Performance on Branching. Contact your instructor.

COMPLETE: A review of all materials you have covered on the subject of branching.

COMPLETE: Performance Checklist F1-6.4. Contact your instructor.

COMPLETE: Written Exam F1-6.5. Contact your instructor.

BRANCHING MACHINE LANGUAGE

RESOURCES

F1-6

1. MCS-80/85 FAMILY USERS MANUAL (Intel, 1979).
2. Zumchak, MICROCOMPUTER DESIGN AND TROUBLESHOOTING (Howard Sams, 1982).
3. Leventhal & Walsh, MICROCOMPUTER EXPERIMENTATION WITH THE INTEL SDK 85 (Prentice Hall, 1980).
4. Hall, MICROPROCESSOR AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Edition.
5. Bery, MICROPROCESSOR AND HARDWARE INTERFACING & APPLICATIONS (Merrill, 1984).
6. PERIPHERAL DESIGN HANDBOOK (Intel, 1981).
7. Goody, THE INTELLIGENT MICROCOMPUTER (SRA, 1982).
8. Larsen, Titus, & Titus, 8085A COOKBOOK (Howard Sams, 1982).
9. Titus, Rony, Larsen & Titus, 8080/8085 SOFTWARE DESIGN BOOK I (Howard Sams, 1982).
10. Larsen, Titus, & Titus, 8080/8085 SOFTWARE DESIGN BOOK II (Howard Sams, 1981).

INFORMATION SHEET

F1-6.1

BRANCHING

The programs that you have written were very simple, straight-line programs, lacking the ability to loop forward or backward on itself. They lack, what is referred to as the ability to "branch". With the ability to branch, comes the ability to write programs which can make simple decisions and branch accordingly.

The branch group of instructions initiates conditional or unconditional jumps, calls, returns, and restarts. Most basic are the jump instructions. The jump instructions are divided into two groups, unconditional and conditional. The unconditional will cause execution to jump to a new position in the program under all conditions. All that needs to be given is the address where the program is to jump. An example of the jump instruction would be, JMP 205Ah. This represents the mnemonic JMP and the address where the program is to jump. In this case, the program will jump to address 205A. Assemblers also provide for the use of implicit addressing. The location in the program where the branch is to go may be marked by a label. For example, location 205A might have a label, LOOP: and then the branch could look like this: JMP LOOP. This is a great aid to programming as it relieves the programmer of keeping track of the absolute address of places in memory.

The conditional jumps provide more instructions, and more power. These instructions give the program decision making capabilities. Jumps are executed or not based on the condition of the flags in the flag register. JZ (jump if zero) will cause the program to branch if the zero flag has been set, i.e. when an arithmetic instruction results in zero. JC (jump if carry) works off of the carry flag, and will cause a jump if there was a carry resulting from the last instruction. JP (jump if plus) works off the sign flag and is used to monitor the MSB to see if it is a 0. If it is, the number is positive and a jump will take place. The last conditional jump is JM, the opposite of the JP instruction, for it is going to create a jump if the number is negative.

It should be obvious that these instructions will allow your program to monitor many operations and conditions. These instructions will give your programs a tremendous amount of power; however, if they are not used properly they will cause you a greater amount of grief. If you are not careful you will have your program jumping all over the place and entering loops that only the "reset" button can get you out of.

Another branch group is the Call instructions. These instructions allow you to write what are referred to as subroutines. A subroutine could be described as a group of instructions or sub-program designed to perform a single specialized task that is required by the main program. These instructions are probably the most powerful of any in the instruction set. Much like the jump set, there is an unconditional call and a conditional call. One of the biggest differences between the jump and call groups is the use of the stack by the call instructions. The CALL instruction uses the stack to save the value in the program counter. You will remember that the program counter contains the address of the next instruction to be executed. After the contents of the PC are "pushed" onto the stack, the address of the subroutine is loaded into the program counter and execution continues at that address. When the subroutine concludes its duties, a RET (return) instruction is issued. This instruction retrieves the old value of the program counter from the stack and places it in the program counter, thus returning execution to the place where the program left off. Every time a CALL is used, a RET instruction must be used in the subroutine. This allows the subroutine to direct the flow of the program back into the main program. Later, in another learning guide, we will investigate the call instructions and the stack in more detail.

A small group which has not been formally introduced is the logical group. This set of instructions compares, rotates, or complements data in registers or memory and includes such instructions as AND, OR and XOR. This set of instructions has numerous uses for manipulating data, setting bits, and masking bits. These instructions are often used to manipulate individual bits in a piece of data or to set flags. The compare instructions in this group are handy to allow quick comparisons of data.

This learning guide has introduced a lot of new instructions, and many of them are complicated to use and understand. It will be absolutely necessary that you investigate every one of these instructions in the user's manual. You should have an understanding of what each of these instructions will do, what its opcode is, and how and where it could be used in a program. After mastering this group of instructions, you should be able to write some pretty complicated and powerful programs.

ACTIVITY SHEET

F1-6.2

BRANCHING

On a separate sheet of paper perform all of the activities called for.

1. List and describe all of the instructions in the Branch group.

2. List and describe all of the instructions in the Logical group.

3. Write a simple program loading ten sequential areas of memory with zero. (Use the conditional jump instructions.)

4. Write a simple subroutine to create a timing delay. (This will involve the use of registers as counters to control your looping.) Remember this is a subroutine, so don't load it where the main program will go; put it at address 2070. This will be its "calling address".

ACTIVITY SHEET F1-6.2

ANSWER SHEET

1. The branch group of instructions and their description can be found in the user's manual.

2. The logical group of instructions and their description can also be found in the user's manual.

3. The program for problem 3 might appear like this:

```
ADDR. OPCODE   LABEL    MNEMONIC       COMMENTS

2000  210D20   START:   LXI H,WORD1    ;Load 1st address
2003  060A              MVI B,10       ;Initialize loop counter
2005  AF                XRA A          ;Zero the accumulator
2006  77       LOOP:    MOV M,A        ;Store zero to memory
2007  23                INX H          ;Increment memory address
2008  05                DCR B          ;Decrement counter
2009  C20620            JNZ LOOP       ;Loop if not done
200C  76       STOP:    HLT            ;Stop when finished
200D           WORD1:   DS  10         ;Define 10 bytes
```

4. The subroutine for your delay might look like this:

```
ADDR. OPCODE   LABEL    MNEMONIC       COMMENTS
2070  1E00     DELAY:   MVI E,00       ;Set outside loop counter
2072  1668              MVI D,104      ;Set inner loop counter
2074  1D       LOOP:    DCR E          ;Decrement outer counter
2075  C27420            JNZ LOOP       ;Loop until zero
2078  15                DCR D          ;Decrement inner counter
2079  C27420            JNZ LOOP       ;Loop until zero
207C  C9                RET            ;Return to calling routine
```

Problem number 4 represents a nested loop, that is, one loop is inside another. This is quite common in delay. You should notice that the subroutine is not part of a main program. It will be up to you to write a main program to test your subroutine. You should also be aware of the return command; every subroutine must end with one.

ACTIVITY SHEET

F1-6.3

SIMPLE BRANCHING MACHINE LANGUAGE PROGRAMS

DIRECTIONS: On a separate piece of paper complete the activities listed below:

1. Write and run a simple program which will wait for a switch closure from one bit on an input port (hex port 21). Figure F1-6.3-1 might serve as the switch interface to your trainer. Figure F1-6.1-2 may be used to output data to lights for program number 6.

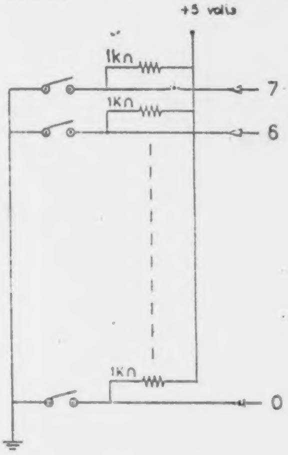


Figure F1-6.3-1

2. Write a program which waits for a switch attached to bit 4 on port 21 to be closed. Modify the program for bits 2, and then 6.

3. Write a program which waits for two switch closures. (Try bits 2 and 5.)

4. Write a program which waits for switches attached to bits 2 and 5 to be closed at the same time and then for switches at 0 and 7 to be closed at the same time.

5. Write and run a program which will wait for a special pattern to occur. (Use 7F)

ACTIVITY SHEET F1-6.3 CONT'D.

6. Write and run a program which will turn on the Leds attached to a port of your trainer for a brief period of time. This will be used later as a "delay routine."

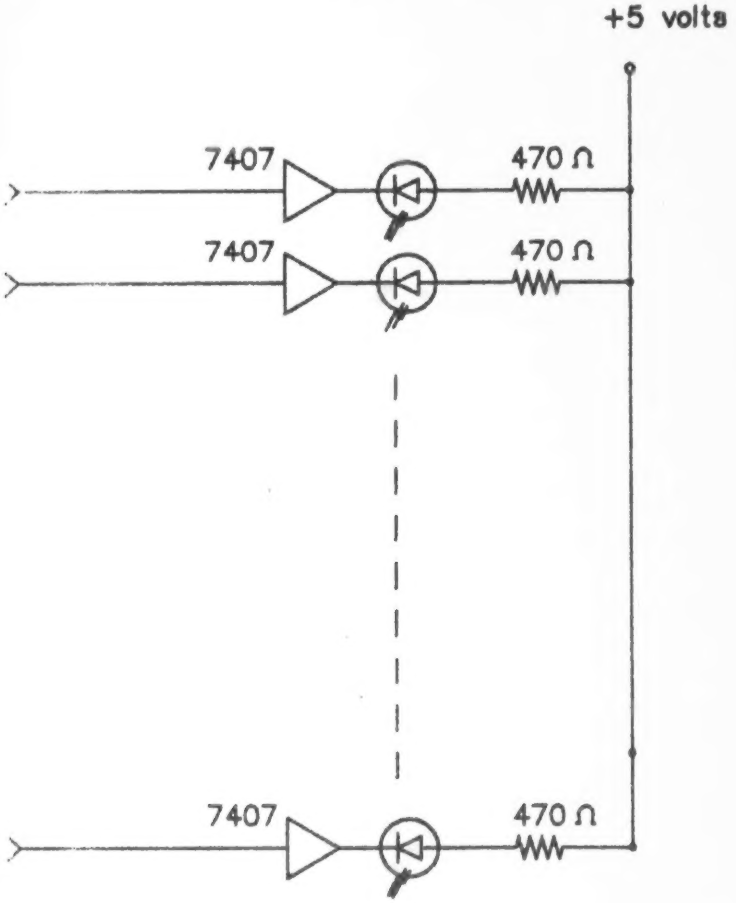

+5 volts
7407
470 Ω
7407
470 Ω
7407
470 Ω

Figure F1-6.3-2

ACTIVITY SHEET F1-6.3

ANSWER SHEET

```
ADDRESS                 INSTRUCTION            COMMENTS
(HEX)                   (MNEMONIC)
---------------------------------------------------------------
```

PROGRAM 1.

```
2000                    MVI  A,OE          ;Init.8155 chip
                        OUT  20H           ;To command status reg.
      WAITC:            IN   21            ;Get input data
                        ANI  20H           ;Is switch closed?
                        JNZ  WAITC         ;No, wait
                        RST  1             ;Break point
---------------------------------------------------------------
```

PROGRAM 2.

The only modification required would be to change the data after the ANI instruction to reflect the new bit pattern. The previous pattern in binary, was 00100000. The ANI instruction causes the data following the ANI to be added the contents of the accumulator. The proper "Mask" for bit 4 would be 10H or 00010000B. For bit 2 it would be 04H or 00000100B, and for bit 6 it would be 40H or 01000000B.

PROGRAM 3.

```
2000                    MVI  A,OE          ;Initi. 8155 chip
                        OUT  20H           ;Program status reg.
      WAIT1:            IN   21H           ;Get input data
                        ANI 00000100       ;Is swtich at bit two closed?
                        JNZ  WAIT1         ;No, wait
      WAIT2:            IN   21H           ;Get input data
                        ANI  00100000      ;Is switch at bit 5 closed?
                        JNZ  WAIT2         ;No, wait
                        RST  1             ;Breakpoint
---------------------------------------------------------------
```

PROGRAM 4.

```
2000                    MVI  A,OE          ;Initi. 8155 chip
                        OUT  20H           ;Command status register
      WAIT1:            IN   21H           ;Get input data
                        ANI 00100100       ;Are switches 2 and 5 closed?
                        JNZ  WAIT1         ;No, wait
      WAIT2:            IN   21H           ;Get input data
                        ANI  10000001      ;Are switches 0 and 7 closed?
                        JNZ  WAIT2         ;No, wait
                        RST  1             ;Breakpoint
---------------------------------------------------------------
```

ACTIVITY SHEET F1-6.3 CONT'D.

ANSWER SHEET

PROGRAM 5.

```
2000             MVI  A,OE       ;Initilize  8155 chip
                 OUT  20H        ;Send to command stat. reg.
     WTCHR:      IN   21H        ;Get data
                 CPI  7FH        ;Is it starting character?
                 JNZ  WTCHR      ;No, wait
                 RST  1          ;Breakpoint
```

PROGRAM 6

```
2000 START:      MVI  A,OE       ;Initialize 8155
                 OUT   20H       ;Send to command status reg.
     AGAIN:      MVI  A,00H      ;Fill a with zeros
                 OUT  22H        ;Turn all lights on
                 LX1  D,OFFFH    ;Initialize delay loop
     DELAY:      DCR  D          ;Delay
                 JNZ  DELAY      ;Test
                 DCR  E          ;Still in delay
                 JNZ  DELAY      ;Loop 1-max delay
                 MVI  A,OFFH     ;Fill a with ones
                 OUT  22H        ;Turn off all lights
     DELAY1:     DCR  D          ;Delay
                 JNZ  DELAY1     ;In the delay
                 DCR  E          ;Still in delay
                 JNZ  DELAY1     ;Loop 2-max. delay
                 JMP  AGAIN      ;Do it again
```

PROGRAM: ELECTRONICS

TASK: BRANCHING MACHINE LANGUAGE

TASK # F1-6.4

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ___________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Write, enter, verify and run machine language branching programs.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation contact your instructor. You must complete your performance within 40 minutes and must score at least 8 out of 10 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 8 out of 10 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

BRANCHING MACHINE LANGUAGE

F1-6.4

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required date recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

STUDENT'S SCORE _____

BRANCHING MACHINE LANGUAGE

EXAM F1-6.5

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on branching machine language. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F1-6.5

1. The instruction JNZ will ______________.

   A. cause the program to jump if the zero flag is set
   B. cause the program to jump if the zero flag is reset
   C. cause the program to jump to a subroutine
   D. none of the above

2. The instruction JC will ______________.

   A. make the program jump if a carry bit was produced
   B. cause the program to produce a carry bit
   C. make the program jump if no carry was produced
   D. none of the above

3. When using the jump instructions the second byte is the ______________.

   A. high-order address location
   B. the low-order address location
   C. the subroutine address
   D. all of these

4. To cause your program to branch if a number was not zero you would use ______________.

   A. the JC instruction
   B. the JNC instruction
   C. the JP instruction
   D. the JNZ instruction

5. If you wanted your program to halt with the detection of a negative number you would use ______________.

   A. JNC
   B. JMP
   C. JM
   D. JP

6. Without some form of "test" in your program the use of a conditional jump will ______________.

   A. have no effect
   B. cause you to enter an infinite loop
   C. go to a halt
   D. all of these

7. If you use a subroutine it must have _____________.

   A. halt instruction
   B. a return instruction
   C. a loop
   D. set of loops

8. If you wanted to OR a piece of data you would _____________.

   A. add one to the data
   B. subtract ones from the data
   C. use the instruction ANA r
   D. none of the above

9. A quick way to change all of the ones to zero in a piece of data is to _____________.

   A. use the instruction CMA
   B. use the instruction RLC
   C. use the instruction ORI
   D. none of these

10. The conditional branch instructions branch based on the condition of the _____________.

    A. B reg
    B. C reg
    C. the stack pointer
    D. the flag reg

EXAM KEY F1-6.5

1. B
2. A
3. B
4. D
5. C
6. B
7. B
8. D
9. A
10. D

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (8085)

F1-7: STACK OPERATIONS

TASK:	Write, enter, verify, and run machine programs demonstrating the operation of the stack.
PURPOSE:	This learning guide will provide you more experience writing simple subroutines. It will also introduce you to the stack and the instructions associated with it. After you have completed this learning guide, you should be able to use instructions that manipulate the stack, and subroutines which will store data on the stack.
OBJECTIVE:	Given all the necessary tools, reference materials, and equipment, you will write, enter, verify and run machine language programs demonstrating the operation of the stack. To master this task you must score 80% on a performance checklist in 40 minutes or less, and 80% on a written exam.

ESTIMATED CLASS TIME: 12 HOURS

STACK OPERATIONS

LEARNING STEPS

F1-7

READ: Information Sheet F1-7.1 on "Operations of the Stack."

READ: Information on stack operations from the following resource list.

COMPLETE: Activity Sheet F1-7.2 on "Stack Operations" and F1-7.3 "Simple Machine Language Programs."

COMPLETE: Lab performances on stack operations. Contact your instructor.

COMPLETE: A review of all the material you have studied on the operation of the stack.

COMPLETE: Performance Checklist F1-7.4 on "Stack Operations." Contact your instructor.

COMPLETE: Written Exam F1-7.5 on "Stack Operations." Contact your instructor.

STACK OPERATIONS

RESOURCES

F1-7

1. MCS-80/85 FAMILY USERS MANUAL (Intel, 1979).
2. Zumchak, MICROCOMPUTER DESIGN AND TROUBLESHOOTING (Howard Sams, 1982).
3. Leventhal & Walsh, MICROCOMPUTER EXPERIMENTATION WITH THE INTEL SDK 85 (Prentice Hall, 1980).
4. Hall, MICROPROCESSOR AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Edition.
5. Bery, MICROPROCESSOR AND HARDWARE INTERFACING & APPLICATIONS (Merrill, 1984).
6. PERIPHERAL DESIGN HANDBOOK (Intel, 1981).
7. Goody, THE INTELLIGENT MICROCOMPUTER (SRA, 1982).
8. Larsen, Titus, & Titus, 8085A COOKBOOK (Howard Sams, 1982).
9. Titus, Rony, Larsen & Titus, 8080/8085 SOFTWARE DESIGN BOOK I (Howard Sams, 1982).
10. Larsen, Titus, & Titus, 8080/8085 SOFTWARE DESIGN BOOK II (Howard Sams, 1981).

INFORMATION SHEET

F1-7.1

OPERATIONS OF THE STACK

The stack is described as a block of successive memory locations (software stack) or CPU registers (hardware stack) for temporary storage. Most processors use a software stack, and it is located in user RAM. The length of a software stack will depend on the size and complexity of programs being written.

To keep track of where the stack is located in memory, the CPU uses a 16-bit register called the "stack pointer" to point at (contain the address of) the top of the stack. The stack is sometimes compared to a stack of dishes stacked on a spring-loaded dispenser, in that the first dish on is the last dish off. This process is the same for the stack; the first piece of data stored in the stack is the last piece of data that may be taken off of the stack.

The microprocessor has a group of instructions which allow the user to place information on the stack and take it off. These instructions are in the group classified as Stack, I/O, and Machine Control Group. At this time we are going to concern ourselves with the stack instructions.

PUSH RP is short for push a register pair. The contents of the high-order register of the specified register pair are moved to the memory location whose address is one less than the content of the stack pointer. The contents of the low-order register pair is moved to the memory location whose address is two less than the contents of the stack pointer. The stack pointer is automatically decremented to reflect the addition of the new data which has been added to the stack. It will now point to the new top of the stack. This instruction allows the user to temporarily save information from a register pair on the stack. It is often used as part of a subroutine, so that data in the registers from the main program can be saved before the subroutine destroys register content.

PUSH PSW is short for push the contents of the flag register on the stack; it also saves the accumulator. The content of the accumulator is moved to the memory location whose address is one less than the stack pointer. The contents of the flag register are moved to the memory location whose address is two less than the content of the stack pointers count.

POP RP is short for pop a register pair off of the stack. It takes the contents of the memory location whose address is specified by the contents of the stack pointer and moves it to the low-order register in the register pair. The contents of the memory location whose address is one more than the content of the stack pointer is moved to the high-order register of the register pair. The POP instruction is the instruction used to get information off of the stack. When you are using the stack, remember that for every PUSH you will have to have a POP to get out all the information you put in.

POP PSW is, naturally, the instruction which allows you to retrieve the flag register and the accumulator from the stack. The first of these two off will be the flag register, because it was the last on; next will come the accumulator.

XTHL is an instruction which allows you to exchange the top of the stack with registers H and L. The L register contents is exchanged with the stack's top location, and the H register contents is exchanged with the stack's next location. Many times the user's manual will show the transfer symbolically; it might appear like this (L)-((SP)) (H)-((SP) + 1). If you study the diagram you will see that it is merely a short-hand method of telling you how the transfer is made.

SPHL is the last instruction in the stack group; it merely allows you to move the contents of the H and L register pair to the stackpoint.

LXI SP is grouped with the data transfer instructions, but it does relate to the stack. It allows the user to load the stack pointer with an address; in other words, it allows you to locate the stack in memory. This instruction should always be used prior to calling the first subroutine, for it marks the position of the stack in memory.

At this point an example might serve to show the use of stack operations and their connection to subroutines. Listed below is a simple subroutine found in the monitor of a microprocessor trainer which allows the user to display four hex digits in the address portion of LED display. If you study the routine, you will see that it has two subroutines "nested," a common practice with many programmers.

This program displays a 4-digit hexadecimal (base 16) count in the address field of the display, using the UPDAD routine from the monitor.

INFORMATION SHEET F1-7.1 CONT'D.

```
ADDRESS  DATA               SYMBOLIC          COMMENTS

2000     31C220             LXI SP 20C2       ;init. stack pointer
2003     13        LOOP:    INX D             ;add 1 to 16-bit count
2004     D5                 PUSH D            ;save count on the stack
2005     CD6303             CALL UPDAD        ;display the count
2008     110018             LXI D,1800        ;set delay count
200B     CDF105             CALL DELAY        ;wait out the delay
200E     D1                 POP D             ;restore count to D&E regs
200F     C30320             JMP LOOP          ;keep counting
```

ACTIVITY SHEET

F1-7.2

STACK OPERATIONS

On a separate sheet of paper perform the activities called for.

1. List and define all of the stack operations.
2. Write a short subroutine to create a variable delay. The delay will be determined by the contents of the register pair DE.
3. Write a simple program to save all of the registers on the stack, and to then retrieve them from the stack.

ACTIVITY SHEET F1-7.2

ANSWER SHEET

1. Refer to information sheet or to the user's manual.

2.

```
ADDR. OPCODE   LABEL     MNEMONIC       COMMENTS

2070  1B       DELAY:    DCX D          ;Start delay count down
2071  7A                 MOV A,D        ;Get delay count
2072  B3                 ORA E          ;DE contain zero?
2073  CF7020             JNZ START      ;No
2076  C9                 RET            ;Return to calling routine
```

This is one way of writing a delay routine. There are many more. To test your routine you will have to write a program and call your subroutine from that program.

3.

```
ADDR. OPCODE   LABEL     MNEMONIC       COMMENTS

2000  31C220   START:    LXI SP,20C2h   ;Initialize stack
2003  21aaaa             LXI H,aaaah    ;Load data into HL
2006  01bbbb             LXI B,bbbbh    ;Load data into BC
2009  11cccc             LXI D,cccch    ;Load data into DE
200C  3E00               MVI A,0        ;Zero accumulator
200E  C5                 PUSH B         ;Push data onto stack
200F  D5                 PUSH D
2010  E5                 PUSH H
2011  F5                 PUSH PSW
2012  CD7020             CALL DELAY     ;Delay
2015  F1                 POP PSW        ;Restore registers
2016  E1                 POP H
2017  D1                 POP D
2018  C1                 POP B
2019  76                 HLT            ;Stop & examine regs.
```

Your program might vary from this one; it will make no difference as long as all the data you had in registers was saved.

ACTIVITY SHEET F1-7.3

SIMPLE MACHINE LANGUAGE PROGRAMS

DIRECTIONS: On a separate piece of paper complete the activities listed below.

1. Write a subroutine that identifies which of the eight switches attached to a port has been closed.

2. Write a subroutine which loads a decimal digit from the address in registers H and L, converts it to a seven-segment code, and shows it on the rightmost display.

3. Load and execute the display program from the monitor of your microprocessor trainer. Check the trainer manual for its address in the monitor.

4. Load and execute the read keyboard subroutine from the monitor of your trainer. Again, check the manual for its address.

5. Write and run a program which will link these two subroutines together.

6. Write and run a program which will flash "FO" on the display of your trainer. Use subroutines from the monitor.

ACTIVITY SHEET F1-7.3

ANSWER SHEET

1.

```
ADDRESS                   INSTRUCTION                COMMENTS
(HEX)                     (MNEMONIC)
------------------------------------------------------------------
2080        IDSW:         MVI   B,OFFH        ;Switch number=-1
            SRCHS:        INR   B             ;Increment switch number
                          RAR                 ;Is next switch open?
                          JC    SRCHS         ;No, keep looking
                          RET                 ;Back to main program
------------------------------------------------------------------
```

NOTE: This is only a subroutine, not a program which will stand by itself. All of the initialization of ports would be done in the main program.

SUBROUTINE NUMBER 2.

```
2080        DSP1:         MVI   B,OFFH        ;Get blank code
                          MOV   A,M           ;Get data
                          CPI   10            ;Is it a decimal digit?
                          JNC   DONE          ;No, done
                          CALL  CNVSS          ;Yes, convert to 7-seg.code
            DONE:         MVI   A,85H         ;Activate rightmost display
                          STA   1900H         ;8279 command reg.
                          MOV   A,B           ;Send code to display
                          STA   1800H         ;8279 chip
                          RST   1             ;Break point

            CNVSS         MOV   L,A           ;Extend digit to 16 bits
                          MVI   H,O           ;Zeros in H
                          LXI   D,SSEG        ;Access seven-seg.code
                          DAD   D             ;Index table
                          MOV   B,M           ;Get seven-seg. code
                          RET

            SSEG:         DB    OCH, 9FH, 4AH, 0BH, 99H, 29H,28H,8FH,08H
                          DB    89H
------------------------------------------------------------------
```

ACTIVITY SHEET F1-7.3 CONT'D.

ANSWER SHEET

NOTE: This subroutine has what is called a nested subroutine, that is, a subroutine within a subroutine. Again, these are subroutines and not main programs. All of the initialization and data (codes) will have to be handled by the main program.

SUBROUTINE NUMBER 3.

```
2000      SETSTK:   LXI  SP,20C2H  ;Set the stack pointer
          INITA:    MVI  A,12H     ;Place hex 12 in A.
                    CALL 036EH     ;Display contents of reg. A
                    JMP  INITA     ;Repeat until reset
------------------------------------------------------------------
```

NOTE: The display address for your monitor may be different from the one shown in this example.

SUBROUTINE NUMBER 4.

```
2000      SETSTK:   LXI  SP,20C2H  ;Must always set stack
          INITA:    MVI  A,OEH     ;Enable RST5.5 for
                    SIML           ;Keyboard subroutine
          REPEAT:   CALL 02E7H     ;Call keyboard subroutine
                    JMP  REPEAT:   ;Do until a reset
------------------------------------------------------------------
```

NOTE: The subroutine for read keyboard lives at address 02E7H in this monitor. In your monitor it might be at a different address.

SUBROUTINE NUMBER 5.

```
2000      INTSP:    LXI  SP,20C2H  ;Always set the stack pointer
                    MVI  A,OEH     ;Enable keyboard interrupts
                    SIM            ; ""    ""    ""      ""
          START:    CALL 02E7H     ;Call keyboard sub.
                    CALL 036EH     ;Call display sub.
                    JMP  START     ;Repeat until a reset
------------------------------------------------------------------
```

ACTIVITY SHEET F1-7.3 CONT'D.

ANSWER SHEET

SUBROUTINE NUMBER 6

```
2000      INTSP:    LXI  SP,20C2H  ;Always set the stack pointer
          FLASH:    MVI  A,OFOH    ;Set A=FO
                    CALL 036EH     ;Call the display sub.
                    LXI  D,0000H   ;SetD&E for max. delay
                    CALL 05F1H     ;Monitor delay~0.33sec.
                    MVI   B,00H    ;Set be to clear display prog.
                    CALL 01D7H     ;Call a monitor clear sub.
                    LXI  D,0000H   ;Reset D&E for max delay
                    CALL 05F1H     ;Monitor delay ~ 0.3 seconds
                    JMP  FLASH     ; Repeat until A reset
-----------------------------------------------------------------
```

NOTE: This subroutine calls for three subroutines: one for a display, one for a delay and one to clear the display. All of these subroutines are found in the monitor program. One other point you should know at this time. Anything in the registers will be destroyed by these subroutines.

PROGRAM: ELECTRONICS

TASK: STACK OPERATIONS

TASK # F1-7.4

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ___________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Write, enter, verify, and run machine programs demonstrating the operation of the stack.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

STACK OPERATIONS

F1-7.4

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required date recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

STUDENT'S SCORE ______

STACK OPERATIONS

EXAM F1-7.5

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on stack operations. Each of the statements is either true or false. Place the letter associated with that choice (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F1-7.5

1. The hardware stack is a group of CPU registers.

   A. True
   B. False

2. Most processors use hardware stacks.

   A. True
   B. False

3. The stack pointer is an 8-bit register whose function is to point to the location of the stack in memory.

   A. True
   B. False

4. The PUSH instruction is used to push information off of the stack.

   A. True
   B. False

5. POP PSW affects the flag and accumulator.

   A. True
   B. False

6. The symbols (L) - ((SP)) (H) - ((SP)+1) indicates the H register is exchanged first.

   A. True
   B. False

7. You initialize the stack with the instruction LXI, SP.

   A. True
   B. False

8. The instruction SPHL allows the user to move the stack to the DE register pair.

   A. True
   B. False

9. For every PUSH instruction you must use a POP instruction.

   A. True
   B. False

10. The PUSH and POP instructions are only used with subroutines.

    A. True
    B. False

EXAM KEY F1-7.5

1. A
2. B
3. B
4. B
5. A
6. B
7. A
8. B
9. A
10. B

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (8085)

F1-8: ALGORITHMS

TASK: Write, enter, verify, and run machine language programs demonstrating the operation of simple algorithms.

PURPOSE: This learning guide will provide an introduction to simple algorithms. After completing this guide, you should have some comprehension of algorithms and how to use them. You should also develop the skill of using flow charts to set up the basic logic of you machine language programs. The process of using break points and single-stepping will also be introduced.

OBJECTIVE: Given access to all necessary tools, equipment, and reference material, you will write, enter, verify, and run machine language programs demonstrating the operation of simple algorithms. To master this task you must score 80% on a performance checklist in 40 minutes or less and 80% on a written exam.

ESTIMATED CLASS TIME: 12 HOURS

ALGORITHMS

LEARNING STEPS

F1-8

READ: Information Sheet F1-8.1 on "Algorithms, Flowcharts, and Debugging."

READ: Information on algorithms, flowcharts, and debugging from the following resource list.

COMPLETE: Activity Sheet F1-8.2 on "Algorithms, Flowcharts, and Debugging."

COMPLETE: Lab performances on algorithms, flowcharts, and debugging. Contact your instructor.

COMPLETE: A review of all materials you have studied concerning algorithms, flowcharts, and debugging.

COMPLETE: Performance Checklist F1-8.3 on "Algorithms, Flowcharts, and Debugging." Contact your instructor.

COMPLETE: Written Exam F1-8.4 on "Algorithms, Flowcharts, and Debugging." Contact your instructor.

ALGORITHMS

RESOURCES

F1-8

1. *MCS-80/85 FAMILY USERS MANUAL* (Intel, 1979).
2. Zumchak, *MICROCOMPUTER DESIGN AND TROUBLESHOOTING* (Howard Sams, 1982).
3. Leventhal & Walsh, *MICROCOMPUTER EXPERIMENTATION WITH THE INTEL SDK 85* (Prentice Hall, 1980).
4. Hall, *MICROPROCESSOR AND DIGITAL SYSTEMS* (McGraw-Hill, 1983). 2nd Edition.
5. Bery, *MICROPROCESSOR AND HARDWARE INTERFACING & APPLICATIONS* (Merrill, 1984).
6. *PERIPHERAL DESIGN HANDBOOK* (Intel, 1981).
7. Goody, *THE INTELLIGENT MICROCOMPUTER* (SRA, 1982).
8. Larsen, Titus, & Titus, *8085A COOKBOOK* (Howard Sams, 1982).
9. Titus, Rony, Larsen & Titus, *8080/8085 SOFTWARE DESIGN BOOK I* (Howard Sams, 1982).
10. Larsen, Titus, & Titus, *8080/8085 SOFTWARE DESIGN BOOK II* (Howard Sams, 1981).

INFORMATION SHEET

F1-8.1

ALGORITHMS, FLOWCHARTING, AND DEBUGGING

An algorithm can be described as a prescribed set of well-defined rules or processes for the solution of a problem in a finite number of steps. If you investigate any programming language, you will find algorithms for many problems. For example, you will find a great number of algorithms in the area of mathematics. There are processes for binary addition, multiplication, division, and many other processes you need.

Before we look at an example of a simple algorithm, we should investigate the topics of flowcharting and debugging. Flowcharting is a traditional programming design method, using a set of standard symbols to convey the program logic. A parallelogram represents data input or output. A rectangle represents a processing operation. A diamond indicates that a decision is to be made. A small circle represents a connecting point where two operations meet. Lines with arrows show data flow. And finally, an elongated oval represents a terminal point (program start/end). When using flowcharting as a design tool follow these suggestions: 1) Start by drawing a rough flowchart. Don't worry about neatness. 2) Check the flowchart for possible errors and improvements. Be sure all branches lead somewhere, all variables are initialized, and all decisions make sense. 3) Draw a revised flowchart, and don't worry about its appearance. 4) When you finish coding, debugging, and testing the program, draw a clear flowchart for final documentation. There are many good texts which cover flowcharting and demonstrate their use; make it a point to study this subject in one of them.

Debugging is the process of working all of the problems out of your program. There are many ways of debugging a program, depending on the tools (software type) available to you. Listed below are a few tools you might have as part of your trainer or development system: 1) A breakpoint, which allows the user to stop execution at a point in the program to examine the current status. 2) A single-step facility, which allows the user to execute the program a step at a time. 3) A dump, which displays the contents of an entire section of memory on an out put device. The dump allows the user to see the results of many operations at one time. 4) A trace, which displays the current status of registers and memory locations while the program is executing. Study your trainer's operation manual to determine which of these facilities are available to you and how to use them.

Now that we have introduced the concepts of algorithms, flowcharting, and debugging, let us study an algorithm for adding binary numbers of arbitrary length. The problem is to add two binary numbers whose length can vary. The algorithm requires that the length in bytes be known and that the two numbers be in memory. An example might have the following 8-byte numbers in memory locations 2051 thru 2058 and 2060 thru 2067. The byte count (8) might be in memory location 2050. The flowchart for the problem is shown in Figure F1-8.1-1.

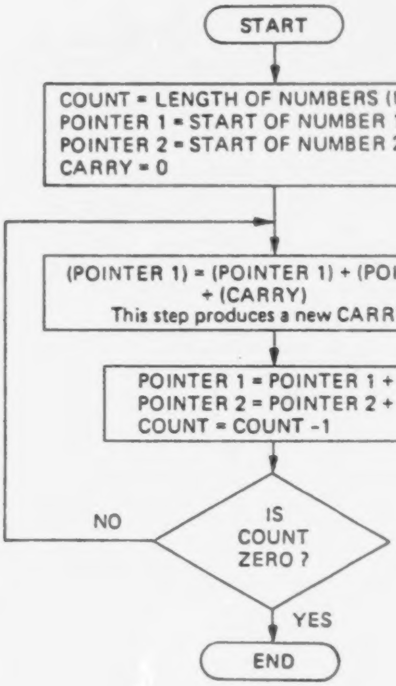

START
COUNT = LENGTH OF NUMBERS (IN BYTES)
POINTER 1 = START OF NUMBER 1
POINTER 2 = START OF NUMBER 2
CARRY = 0
(POINTER 1) = (POINTER 1) + (POINTER 2) + (CARRY)
This step produces a new CARRY
POINTER 1 = POINTER 1 + 1
POINTER 2 = POINTER 2 + 1
COUNT = COUNT -1
IS COUNT ZERO ?
NO
YES
END

Figure F1-8.1-1

The program's logic is blocked out by the flowchart, which will require some study. The program requires two pointers, one to point at the start of the first number in memory and the other to point at the second number. It also requires a counter to keep track of the number of bytes which need to be added (in our example 8). Another requirement is to clear the carry flag so that the add with carry instruction can be used instead of a plain add. This will be accomplished by using the instruction ANA A, which ANDs the accumulator. One clever technique of this algorithm is to put the answer into memory at the same place where one of the numbers to be added was stored. This will save on memory space, which is sometimes limited in small systems. It does have the disadvantages of losing one of the numbers. A more detailed explanation might be accomplished by explaining the logic and program flow in the comments section of coded version of the algorithm.

```
ADDR. OPCODE   LABEL    MNEMONIC       COMMENTS

2000  215020   START:   LXI H,NUM1-1   ;Load number length
2003  46                MOV B,M        ;Number length to reg. B
2004  115920            LXI D,NUM2     ;Point to 2nd number
2007  A7                ANA A          ;Clear Acc and carry
2008  1A       LOOP:    LDAX D         ;Get byte of 2nd number
2009  8E                ADC M          ;Add btye of 1st to 2nd
200A  77                MOV M,A        ;Store result
200B  23                INX H          ;Get next byte of 1st number
200C  13                INX D          ;Get next byte of 2nd number
200D  05                DCR B          ;Decrement count
200E  C20820            JNZ LOOP       ;Loop if not done
2011  CF      EXIT:     RST 1          ;Exit
```

There are many algorithms available to use for whatever problem you might be faced with. Study a text on machine language programming, also read magazines which have articles on machine language programming, after reading these keep a record of what the algorithm is and where it is. If you do this you will soon have a library of processes which you can use to solve a problem you are faced with.

ACTIVITY SHEET

F1-8.2

ALGORITHMS, FLOWCHARTING, AND DEBUGGING

On a separate sheet of paper complete the activities requested.

1. Define the following terms:

   A. Algorithm

   B. Breakpoint

   C. Flowchart

   D. Trace

   E. Single Step

   F. Dump

2. List the four steps used to flowchart a program.

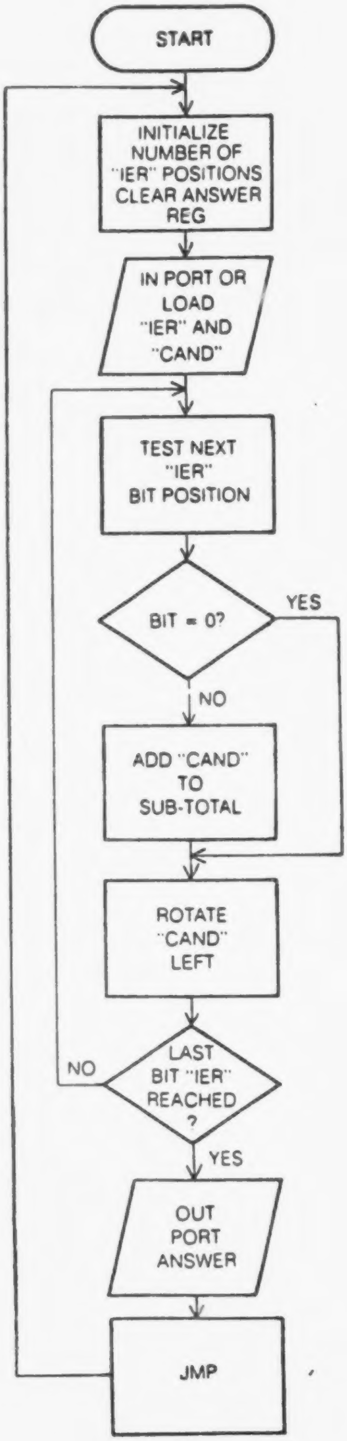
   1.

   2.

   3.

   4.

3. Explain the logic and perform the coding of the binary multiplication algorithm drawn on the left.


START
INITIALIZE NUMBER OF "IER" POSITIONS CLEAR ANSWER REG
IN PORT OR LOAD "IER" AND "CAND"
TEST NEXT "IER" BIT POSITION
BIT = 0?
YES
NO
ADD "CAND" TO SUB-TOTAL
ROTATE "CAND" LEFT
LAST BIT "IER" REACHED ?
NO
YES
OUT PORT ANSWER
JMP

ACTIVITY SHEET F1-8.2

ANSWER SHEET

The answers to questions 1 and 2 will be found in the Information Sheet F1-8.1.

The coding for the algorithm of question 3 should appear something like this:

```
START:  MVI E,nnh     ;number of bits in multiplier
        MVI D, 00     ;clear register

        IN  pph       ;get multiplicand from port pp
        MOV C,A       ;store in reg. C
        IN  qqh       ;get multiplier from port qq

TEST:   RAR
        MOV B,A

        JNC PASSED    ;add multiplicand to sub total

        MOV A,C
        ADD D
        MOV D,A       ;add and save

PASSED: MOV A,C
        RAL
        MOV C,A       ;rotate multiplicand left

        DCR E
        MOV A,B
        JNZ TEST      ;test next multiplier

        MOV A,D
        OUT rr        ;answer to port rr

        JMP START     ;start over
```

I have not provided a complete coding with opcodes and addresses, if you wish to test the program you will have to code it for entry.

PROGRAM: ELECTRONICS

TASK: ALGORITHMS

TASK # F1-8.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ___________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Write, enter, verify, and run machine language programs demonstrating the operation of simple algorithms.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation contact your instructor. You must complete your performance within 40 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

ALGORITHMS

F1-8.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required date recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

STUDENT'S SCORE ____

ALGORITHMS

EXAM F1-8.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on algorithms, flowcharts, and debugging. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F1-8.4

1. Having a program stop at a certain place so that it may be examined is called ______________.

   A. single-stepping
   B. dumping
   C. editing
   D. setting a break point

2. A well defined process for doing a computer problem might be called a(n) ______________.

   A. algorithm
   B. flowchart
   C. logic diagram
   D. logic plan

3. A process for symbolically representing the logic of a program is called a ______________.

   A. logic chart
   B. flowchart
   C. logic plan
   D. algorithm

4. Algorithms are most commonly used for ______________.

   A. input routines
   B. math routines
   C. output routines
   D. none of the above

5. The shape used to represent a decision in a flowchart is the ______________.

   A. diamond
   B. square
   C. oval
   D. rectangle

6. A connecting point in a program is represented by a ______________.

   A. square
   B. diamond
   C. lines
   D. small circle

7. A flowchart block shaped like a parallelogram represents _______________.

   A. input or output
   B. a decision
   C. a connecting point
   D. none of these

8. When starting your flowchart you should _______________.

   A. be very neat
   B. not worry about neatness

9. The instruction ANA A _______________.

   A. will clear the accumulator
   B. will not clear the accumulator

10. Which of the following debugging tools is best for watching the program execution?

   A. single-step
   B. trace
   C. dump
   D. break-point

EXAM KEY F1-8.4

1. D
2. A
3. B
4. B
5. A
6. D
7. A
8. B
9. A
10. B

ELECTRONICS

8085 MICROPROCESSOR

F1-9: INPUT/OUTPUT AND INTERRUPTS

TASK:	Write, enter, verify, and run machine language programs demonstrating the operation of input/output and interrupts.
PURPOSE:	This learning guide will introduce you to input and output operations, as well as the use of interrupts. After you complete this learning guide, you should have an understanding of the input instruction, the output instruction, and instructions which relate to the processor's interrupts. You should also be able to write simple programs with input and output data based on the use of interrupts.
OBJECTIVE:	Given access to all necessary tools and equipment, you will write, enter, verify, and run machine language programs which demonstrate the operation of input/output and interrupts. To master this task you must score 80% on a performance checklist within 45 minutes or less and 80% on a written exam.

ESTIMATED CLASS TIME: 12 HOURS

INPUT/OUTPUT AND INTERRUPTS

LEARNING STEPS

F1-9

READ:	Information Sheet F1-9.1, "Input/Output and Interrupts."
READ:	Information on input/output and interrupts from the following resource list.
COMPLETE:	Activity Sheet F1-9.2, "Input/Output and Interrupts" and F1-9.3, "Simple Machine Language Programs for Input and Output."
COMPLETE:	Lab Performances on input/output and interrupts. Contact your instructor.
COMPLETE:	A review of all materials you have covered on the subject of input/output and interrupts.
COMPLETE:	Performance Checklist F1-9.4 on input/output and interrupts. Contact your instructor.
COMPLETE:	Exam F1-9.5 on input/output and interrupts. Contact your instructor.

INPUT/OUTPUT AND INTERRUPTS

RESOURCES

F1-9

1. MCS-80/85 FAMILY USERS MANUAL (Intel, 1979).
2. Zumchak, MICROCOMPUTER DESIGN AND TROUBLESHOOTING (Howard Sams, 1982).
3. Leventhal & Walsh, MICROCOMPUTER EXPERIMENTATION WITH THE INTEL SDK 85 (Prentice Hall, 1980).
4. Hall, MICROPROCESSOR AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Edition.
5. Bery, MICROPROCESSOR AND HARDWARE INTERFACING & APPLICATIONS (Merrill, 1984).
6. PERIPHERAL DESIGN HANDBOOK (Intel, 1981).
7. Goody, THE INTELLIGENT MICROCOMPUTER (SRA, 1982).
8. Larsen, Titus, & Titus, 8085A COOKBOOK (Howard Sams, 1982).
9. Titus, Rony, Larsen & Titus, 8080/8085 SOFTWARE DESIGN BOOK I (Howard Sams, 1982).

Larsen, Titus, & Titus, 8080/8085 SOFTWARE DESIGN BOOK II (Howard Sams, 1981).

INFORMATION SHEET

F1-9.1

INPUT/OUTPUT AND INTERRUPTS

IN port is an instruction used to bring data into the processor from some external device. The instruction is a two-byte instruction, the second byte specifing the port assignment address of the input. It is a single-byte address, allowing only 256 different input devices, more than enough in most cases. The operation of this instruction is to take the data placed on the eight-bit data bus by the specified port and move it to the accumulator.

OUT port is an instruction used to take data out of the processor and give it to some external device. The instruction reverses the input instruction, taking the contents of the accumulator, placing it on the data bus, and transferring it to the device located at the instruction's second byte address. Both the input and output instructions specify a location for the device; however, not all external devices need be connected by in/out instructions. Many times external devices are assigned an address and treated as memory. This technique is legal, but it will require a two-byte memory address, which will slow the process down to some degree.

The input/output instructions are easy to use and don't require much software to implement, but there must be a hardware interface with the external device, and sometimes these can get a little complicated. Thanks to large-scale integration, making an interface (connection between microprocessor and outside world) today is easier than it was several years ago. One device which has made this job easier is the programmable peripheral interface adapter, PIA. Figure F1-9.1-1 is a functional block diagram for a popular PIA. What is unique about these devices is their ability to be programmed by the processor's software. This feature makes such hardware very flexible. The process of setting one of these devices up with software is called initializing, and must be done before the device can function. The operation and programming explanation of these devices is a bit long for this guide, and unnecessary; their operation and circuitry are best explained by referring to a manufacturer's data book. When researching these devices, look in the section for programmable peripheral devices. An industry standard is the 8255.

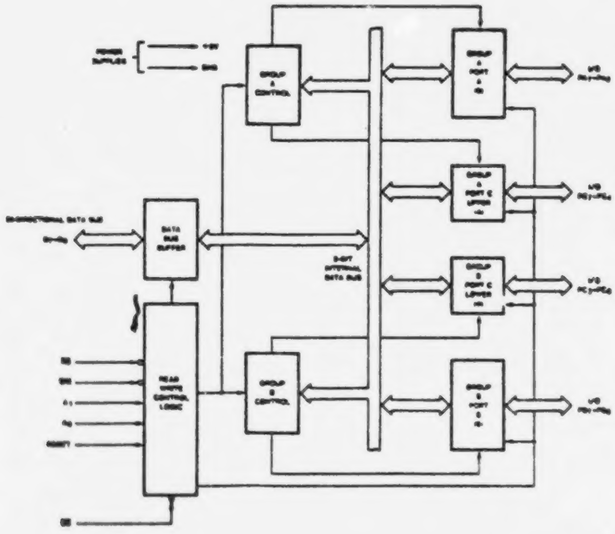


Figure F1-9.1-1

Another interesting peripheral chip, and one which is used quite often on small systems, is the 8155. This chip is unique in that it is a combination of 256 bytes of RAM, several I/O ports and a timer. This device is also programmable, which increases its flexibility. The programming of this device is fairly simple and is explained along with its operation by Figure F1-9.1-2 and Figure F1-9.1-3.

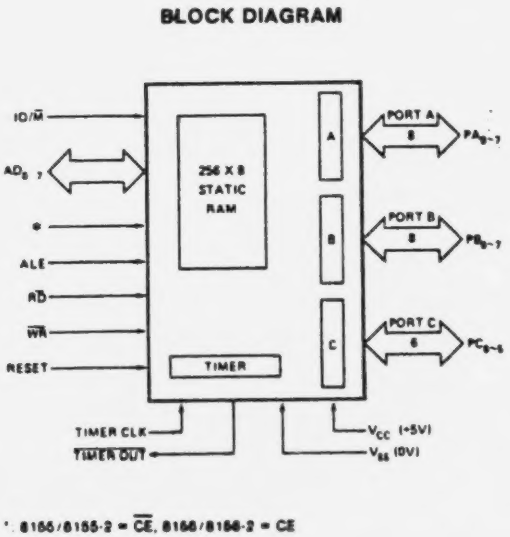

BLOCK DIAGRAM
IO/$\overline{M}$
AD_{0-7}
*
ALE
$\overline{RD}$
$\overline{WR}$
RESET
256 X 8
STATIC
RAM
TIMER
A
B
C
PORT A
8
PA_{0-7}
PORT B
8
PB_{0-7}
PORT C
6
PC_{0-5}
TIMER CLK
$\overline{TIMER OUT}$
V_{CC} (+5V)
V_{SS} (0V)
*: 8155/8155-2 = $\overline{CE}$, 8156/8156-2 = CE

Figure F1-9.1-2

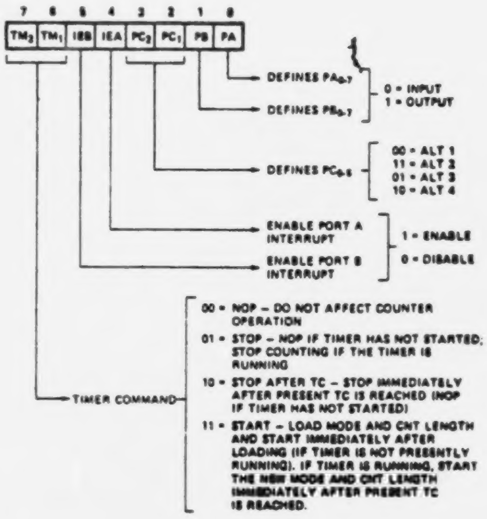

7
6
5
4
3
2
1
0
TM_2
TM_1
IEB
IEA
PC_2
PC_1
PB
PA
DEFINES PA_{0-7}
DEFINES PB_{0-7}
0 = INPUT
1 = OUTPUT
DEFINES PC_{0-5}
00 = ALT 1
11 = ALT 2
01 = ALT 3
10 = ALT 4
ENABLE PORT A INTERRUPT
ENABLE PORT B INTERRUPT
1 = ENABLE
0 = DISABLE
TIMER COMMAND
00 = NOP – DO NOT AFFECT COUNTER OPERATION
01 = STOP – NOP IF TIMER HAS NOT STARTED; STOP COUNTING IF THE TIMER IS RUNNING
10 = STOP AFTER TC – STOP IMMEDIATELY AFTER PRESENT TC IS REACHED (NOP IF TIMER HAS NOT STARTED)
11 = START – LOAD MODE AND CNT LENGTH AND START IMMEDIATELY AFTER LOADING (IF TIMER IS NOT PRESENTLY RUNNING). IF TIMER IS RUNNING, START THE NEW MODE AND CNT LENGTH IMMEDIATELY AFTER PRESENT TC IS REACHED.

Figure F1-9.1-3

The input and output instructions and devices have been introduced, and there will be an activity later in this guide which will give you some experiences using them. We will now move our attention to the processor's interrupts. An interrupt is defined as the suspension of a machine's program execution in order to handle a sudden request for service. Interrupts allow the processor to go about its business of processing data without the constant checking of peripheral devices. An interrupt signals that an external device (printer, keyboard, drive, etc.) needs the processor's attention.

The processor will finish executing the current instruction and branch to a service routine (subroutine) setup to service that particular peripheral.

There are two basic types of interrupts, maskable and nonmaskable. The nonmaskable interrupts are always active and can not be ignored by the processor. The maskable interrupts can be masked so that the processors will ignore them. The number and type of interrupts vary from one processor to another. Some processors have as many as five interrupts and some of the interrupts are the vectored type. A vectored interrupt is an interrupt which is automatically "sent off" to a particular memory location, which has instructions branching it to a service subroutine.

For the 8085 five hardware interrupt inputs are provided. INTR is maskable (can be enabled or disabled by EI or DI software instructions), and causes the CPU to fetch an RST instruction, externally placed on the data bus, which vectors a branch to any one of eight fixed memory locations (Restart addresses). The RST 5.5, RST 6.5, and RST 7.5 hardware interrupts clear or set corresponding mask flags based on data in the accumulator. The third type of hardware interrupt is TRAP. This input is not subject to any mask or interrupt enable/disable instructions.

A more complete description of the interrupts will be found in a user's manual; I suggest you read it. With an understanding of the interrupts found on the microprocessor, it is now time to look at the software which controls them. EI stands for enable interrupts, and is used to enable the interrupt system. The interrupt system is enabled following the execution of the next instruction. Interrupts are not recognized during the EI instruction.

The DI instruction is used to disable interrupts. The system of interrupts will be disabled immediately following the execution of the next DI instruction. Interrupts are not recognized during the DI instruction.

INFORMATION SHEET F1-9.1 CONT'D.

The RIM instruction is used to read interrupt masks. The RIM instruction loads data into the accumulator relating to interrupts and serial input. This data contains the following information: Current interrupt mask status for RST 5.5, 6.5, and 7.5 hardware interrupts (1=mask disabled) Current interrupt enable flag status (1=interrupts enabled) except immediately following TRAP interrupt. Hardware interrupts pending on the RST 5.5, 6.5, and 7.5 lines. And, serial input data.

The SIM instruction is used to set interrupt masks. The execution of the SIM instruction uses the contents of the accumulator (which must be previously loaded) to perform the following functions: Program the interrupt mask for the RST 5.5, 6.5, and 7.5 hardware interrupts. Reset the edge triggered RST 7.5 input latch. And, load the SOD output latch. To program the interrupt masks, first set accumulator bit 3 to logic 1 and set to 1 any bits 0, 1, and 2 which disable the RST interrupts. A more detailed explanation of the SIM and RIM bit codes are displayed by Figure F1-9.1-4.

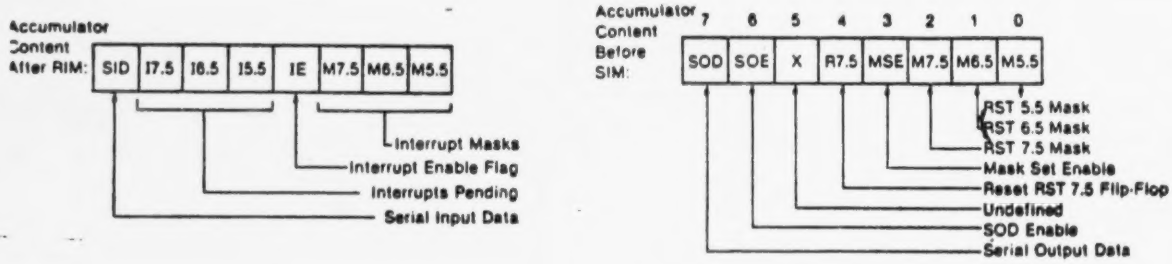

Accumulator Content After RIM:
SID
I7.5
I6.5
I5.5
IE
M7.5
M6.5
M5.5
Interrupt Masks
Interrupt Enable Flag
Interrupts Pending
Serial Input Data
Accumulator Content Before SIM:
7
6
5
4
3
2
1
0
SOD
SOE
X
R7.5
MSE
M7.5
M6.5
M5.5
RST 5.5 Mask
RST 6.5 Mask
RST 7.5 Mask
Mask Set Enable
Reset RST 7.5 Flip-Flop
Undefined
SOD Enable
Serial Output Data

Figure F1-9.1-4

Listed below is a simple program, which is part of a monitor that uses an interrupt to read a keyboard. Study this example to see how the SIM instruction is used along with an RST 5.5 interrupt from the keyboard.

```
ADDR. OPCODE    LABEL     MNEMONIC          COMMENTS
2000 31C220    START:     LXI SP,20C2h      ;initialize stack
2003  3E0E               MVI A,00001110b ;interrupt bit pattern
2005  30                 SIM               ;set interrupt mask
2006  FB                 EI                ;enable interrupts
2007  CDEF20             CALL RDKBD        ;get char from keyboard
200A  CF                 RST 1             ;check accumulator
```

This is only one example of using interrupts with input or output devices; if you study the monitor listing for your microprocessor trainer, you will discover many more. Make it a point to familiarize yourself with interrupts and their uses.

ACTIVITY SHEET

F1-9.2

INPUT/OUTPUT AND INTERRUPTS

On a separate sheet of paper complete all of the activities listed below.

1. Define the operation of

   a. Input instruction
   b. Output instruction

2. Draw a functional block diagram of an 8255 PIA and the interface to the microprocessor.

3. Write a simple program to initialize the 8255 so that port A is an input and port B is an output. (Use mode 0 operation.)

4. Draw a functional block diagram of an 8155, and show its interface to a microprocessor.

5. Write a simple program to initialize the 8155 so that port A is an input and port B is an output.

6. Describe the following 8085 interrupts:

   a. Trap
   b. INTR
   c. RST 5.5
   d. RST 6.5
   e. RST 7.5

7. Describe the operation of these instructions:

   a. DI
   b. EI
   c. SIM
   d. RIM

8. Draw the interrupt mask register as read by the RIM instruction.

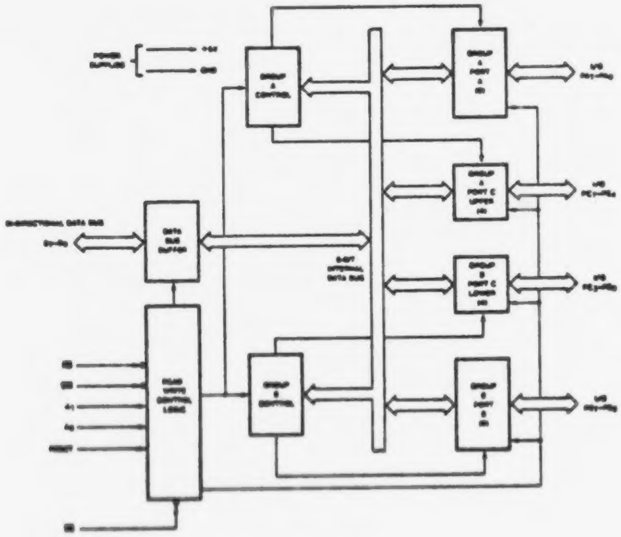
9. Draw the interrupt mask register as set by the SIM instruction.

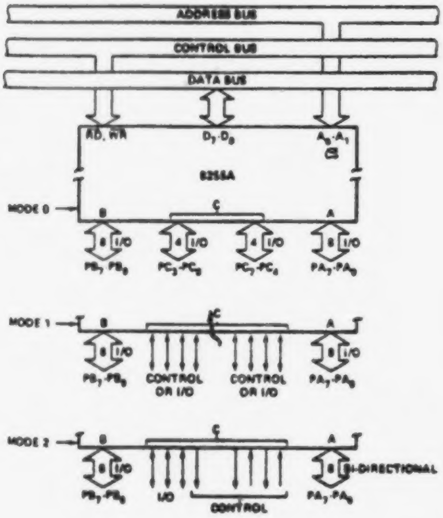
ACTIVITY SHEET F1-9.2

ANSWER SHEET

1. Check text or user's manual for input and output instruction description.

2. See diagrams below.




ADDRESS BUS
CONTROL BUS
DATA BUS
RD, WR
D_7-D_0
A_0-A_1
CS
8255A
MODE 0
B
C
A
8 I/O
4 I/O
4 I/O
8 I/O
PB_7-PB_0
PC_3-PC_0
PC_7-PC_4
PA_7-PA_0
MODE 1
CONTROL OR I/O
CONTROL OR I/O
MODE 2
I/O
CONTROL
BI-DIRECTIONAL

3. Without system addresses the program will be short and list address ports symbolically. Also port C was not specified as to In or Out, so control words might vary. The mode and control words are formed with the following format:

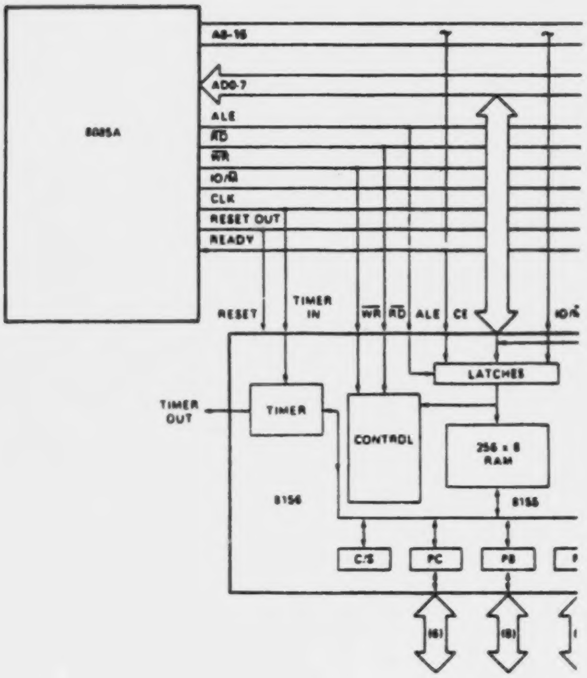
D7	D6	D5	D4	D3	D2	D1	D0	
1	0	0	1	X	0	0	X	(mode word might vary)
1	0	0	1	0	0	0	1	(control word)

```
MVI A
1001X00X    (SET UP CONTROL WORD)
OUT
TO MODE CONTROL  REG.
MVI A
10010001
OUT
TO CONTROL REG.
```

ACTIVITY SHEET F1-9.2 CONT'D.

ANSWER SHEET

4.


8085A
A8-15
AD0-7
ALE
$\overline{RD}$
$\overline{WR}$
IO/$\overline{M}$
CLK
RESET OUT
READY
RESET
TIMER IN
$\overline{WR}$
$\overline{RD}$
ALE
CE
IO/$\overline{M}$
LATCHES
TIMER OUT
TIMER
CONTROL
256 x 8 RAM
8156
8155
C/S
PC
PB
(6)
(8)

5. Your program might appear as follows:

```
MVI A  ;     Set up command reg.
 02    ;     (A as input as output)
OUT    ;     To command reg, location
 20
```

6. 7. 8. AND 9. See the user's manual.

ACTIVITY SHEET

F1-9.3

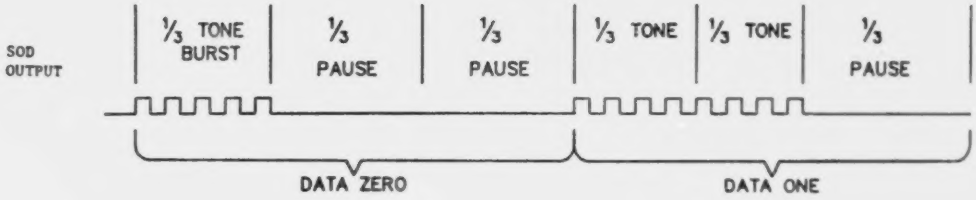
SIMPLE MACHINE LANGUAGE PROGRAMS FOR INPUT AND OUTPUT

DIRECTIONS: On a separate piece of paper complete the activities listed below.

SERIAL INPUT AND OUTPUT:

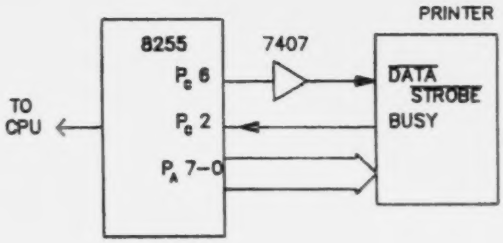
1. Write a subroutine which can be used to read data from or write data onto a cassette recorder. Listed below are some considerations for the program.

   a. Program should read or write one page of data, 256 bytes.
   b. Use register C for data.
   c. Data transmission will follow the format illustrated by Figure 1.
   d. H and L will be used to point to data in memory.
   e. SID and SOD lines will be used for data input and output.


SOD OUTPUT
⅓ TONE BURST
⅓ PAUSE
⅓ PAUSE
⅓ TONE
⅓ TONE
⅓ PAUSE
DATA ZERO
DATA ONE

PARALLEL OUTPUT, STATUS DRIVEN. MODE ZERO CONFIGURATION

2. Using an 8255 PIA write a program to output data to a "Centrontics" type parallel printer. Hardware interface will look like that of figure 2. Use the following program equates: Port A = f4H. Port B = f5H. Port C = f6H. Control word register = f7H. 83H = initialization of 8255. OD = printer data strobe on. OC = printer data strobe off. 04 bit mask for line printer busy. Review 8255 data sheets and application notes before starting this program.


PRINTER
8255
7407
P_C 6
P_C 2
P_A 7–0
TO CPU
$\overline{\text{DATA STROBE}}$
BUSY

ACTIVITY SHEET F1-9.3

ANSWER SHEET

```
1.
ADDRESS             INSTRUCTION                   COMMENTS
(HEX)               (MNEMONIC)
-----------------------------------------------------------------
2800 BLKRCD:        MVI  CC,0FA       ;Set counter for extended burst
                    MVI  A,0C0H       ;Bits 6&7 set for sim  yeilds sq.
     BR1:           CALL BURST        ;Outputs a long tone
                    DCR  C            ;Delay for long tone burst
                    JNZ  BR1          ;Sustain this tone for recorder
                    XRA  A            ;Zero A, set bits 6&7 low=space
                    CALL BURST        ;Start looking for 1st data byte
     BR2:           MOV  C,M          ;Get data to be recorded
                    CALL TAPEO        ;Output register C to recorder
                    INR  L            ;Move memory pointer to next byte
                    JNZ  BR2          ;Not done, get next data byte
                    RET               ;Page is complete
*****************************************************************

     TAPEO:         DI                ;Disable interrupts can's be int.
                    PUSH D            ;Save D&E for the burst routine
                    MVI  B,9          ;Counter for 8 data and 1 stop
     TO1:           XRA  A            ;Clear accumulator
                    MVI  A,0C0H       ;Set bits 6&7 for tone burst
                    CALL BURST        ;Tone burst generated
                    MOV  A,C          ;Position C to A for carry
                    RAR               ;Move data bit into carry
                    MOV  C,A          ;Carry will become sod enable in
                    RAR               ;Burst subroutine
                    RAR               ;Now in bit position A6.
                    CALL BURST        ;Output either A tone or pause
                    XRA  A            ;Clear accum. for pause output
                    CALL BURST        ;Output a pause
                    DCR  B            ;Test for last data bit
                    JNZ  TO1          ;Do until data byte is finished
                    POP  D            ;Restore status and return
                    EI                ;Enable interrupts
                    RET               ;Return
*****************************************************************
     BURST:         MVI  D,0FAH       ;Delay to set number of cycles
     BU1:           SIM               ;Complement sod line if enableset
                    MVI  E,01EH       ;Counter for tone regulation
     BU2:           DCR  E            ;Start tone reg. delay
                    JNZ  BU2          ;Not done, continue tone
                    XRI  80H          ;Complement sod data in accum.
                    DCR  D            ;
                    JNZ  BU1          ;Continue until burst or pause
                    RET               ;Return when burst or pause fin.
*****************************************************************
```

ACTIVITY SHEET F1-9.3 CONT'D.

ANSWER SHEET

```
      PLAYBK:    MVI  C,OFAH      ;Counter to read successive highs
      PB1:       CALL BITIN       ;Bring bit in verify successive
                 JNC  PB1         ;Highs also allows recorder agc.
      PB2:       CALL TAPEIN      ;Get data from recorder
                 MOV  M,C         ;Store data in memory
                 INR  L           ;Move memory pointer
                 JNZ  PB2         ;Repeat for rest of current page
                 RET              ;Return when done
*****************************************************************
      TAPEIN:    MVI  B,9         ;Read 8 data bits on stop
      TI1:       MVI  D,OOH       ;Clear up/dw counter which det.
      TI2:       DCR  D           ;If data one or zero DCR=1
                 CALL BITIN       ;Get bit
                 JC   T12         ;If carry set its one, get anoth.
      T13:       INR  D           ;No carry, its zero INR D by 1
                 CALL BITIN       ;Get a bit
                 JNC  T13         ;If no carry its zero do again
                 CALL BITIN       ;Get another bit
                 JNC  T13         ;Test, nocarry jump else fall
                 MOV  A,D         ;Place final count of D in A
                 RAL              ;Move counter MSB into carry
                 MOV  A,C         ;Move data bit into carry
                 RAR              ;
                 MOV  C,A         ;Save back in C
                 DCR  B           ;Decrease bit counter one
                 JNZ  T11         ;Repeat until full byte assm.
                 RET              ;Return when done
*****************************************************************
      BITIN:     MVI  E,016H      ;Counter for sample rate
      BI1:       DCR  E           ;Start sample loop
                 JNZ  BI1         ;Limit input sample rate
                 RIM              ;Sample sid line
                 RAL              ;Move data into CY bit
                 RET              ;Return when done
                 END              ;End of subroutine
*****************************************************************
*****************************************************************
```

COMMENTS: The playback routine requires presetting H and L to the target address and turning on the recorder before the routine, PLAYBK is called.

As you can see the program is divided into six basic parts. BLKRCD is a subroutine which records a page of data at a memory location pointed at by the H and L register pair. TAPEO is used to output data in the format illustrated by figure number 1. BURST is a subroutine which creates the necessary tone pattern, burst, for data transmission. A burst followed by another burst

ACTIVITY SHEET F1-9.3 CONT'D.

is a logic one; a burst followed by two spaces is a logic zero. PLAYBK is used to input the data from the recorder. It uses two nested routines, TAPEIN and BITIN. Data type is determined by register D. If D is negative, the burst lasted longer than the space, logic 1. Program number 2, parallel output. Program assumes data in memory and will be brought in by way of Register C.

```
2800                CALL  INIT:      ;Initialization routine
     LPST:          IN    OF6H       ;GET STATUS OF PRINTER
                    ANI   04H        ;See if busy
                    MOV   C,M        ;Get first byte to be printed
                    MOV   A,C        ;Move byte from C to A for print
                    OUT   OF4H       ;Output data to data lines on 8255
                    MVI   A,OCH      ;Get data strobe control word
                    OUT   OF7H       ;Send to control word reg. in 8255
                    INR   A          ;Generate set data strobe control
                                      word
                    OUT   OF7H       ;Set data strobe
                    DCR   L          ;Move pointer down one
                    JNZ   LPST       ;Not all bytes printed do until
                                      done
                    RST   1          ;Break point use if you want
*****************************************************************

INITIALIZATION****
     INIT:          MVI   A,83H      ;Initialization control word
                    OUT   OF7H       ;Send to control word register
                    MVI   A,OD       ;Printer data strobe one
                    OUT   OF7H       ;Send to control word register
                    LXI   H,FF28H    ;Memory pointer one page of data
                    RET              ;Return to caller
*****************************************************************
```

PROGRAM: ELECTRONICS

TASK: INPUT/OUTPUT AND INTERRUPTS

TASK # F1-9.4

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ___________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Write, enter, verify, and run machine language programs demonstrating the operation of input/output and interrupts.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 45 minutes and must score at least 8 out of 10 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 45 minutes and must score 8 out of 10 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

INPUT/OUTPUT AND INTERRUPTS

F1-9.4

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required date recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

STUDENT'S SCORE _____

INPUT/OUTPUT AND INTERRUPTS

EXAM F1-9.5

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on input/output and interrupts. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F1-9.5

1. The input instruction can specify ___________.

   A. 256 ports
   B. 65,536 ports
   C. 244 ports
   D. none of the above

2. The contents of which register are put on the data bus with an input instruction?

   A. B reg.
   B. D reg.
   C. flag reg.
   D. none of these

3. PIA is short for ___________.

   A. peripheral interface adapter
   B. peripheral exchange adapter
   C. programmable information adapter
   D. programmable international adapter

4. Which of the following is an industry standard PIA?

   A. 8522
   B. 8652
   C. 8255
   D. 8511

5. Which of the following interface chips have RAM, I/O, and a programmable timer?

   A. 8155
   B. 8255
   C. 8511
   D. 8522

6. The SIM instruction is used to set the interrupt mask on _______________.

   A. the INTR instruction
   B. the TRAP instruction
   C. the RST 5.5
   D. none of these

7. TRAP is a _____________.

   A. maskable interrupt
   B. nonmaskable interrupt

8. Interrupts are ____________.

   A. recognized during the OI instruction
   B. not recognized during the DI instruction

9. The RIM instruction loads data into the ___________.

   A. accumulator
   B. flag register
   C. stackpointer
   D. program counter relating to the interrupts

10. The RIM and SIM instructions are used to set and read status of the serial data lines.

    A. True
    B. False

EXAM KEY F1-9.5

1. A
2. D
3. A
4. C
5. A
6. C
7. B
8. B
9. A
10. A

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (8085)

F1-10: INTERFACING RAM AND DISPLAYS

TASK:	Prepare the software and hardware to perform the interface operations with RAM and display.
PURPOSE:	This learning guide will investigate different types of RAM (random access memory) and its interface to a microprocessor. It will also study 7-segments displays and their connection to a microprocessor. After you complete this learning guide, you should be able to describe the different types of RAM, and draw an addition of RAM to your trainer. Also, you should be able to draw the interface and write the software for a 7-segment display connected to your trainer.
OBJECTIVE:	Given access to all necessary tools and equipment, you will prepare the software and hardware to perform interface operations with RAM and display. To master this task you must score 80% on a performance checklist and 80% on a written exam.

ESTIMATED CLASS TIME: 12 HOURS

INTERFACING RAM AND DISPLAYS

LEARNING STEPS

F1-10

READ: Information Sheet F1-10.1, "Memory."

READ: Information on memory from the following resource list.

COMPLETE: Activity Sheet F1-10.2, "Memory."

READ: Information Sheet F1-10.3, "7-Segment Display Interface."

READ: Information on interfacing 7-Segment displays from the following resource list.

COMPLETE: Activity Sheet F1-10.4, "7-Segment Display Interface."

COMPLETE: A review of all material covered by this guide.

COMPLETE: Performance Checklist F1-10.5. Contact your instructor.

COMPLETE: Written Exam F1-10.6. Contact your instructor.

INTERFACING RAM AND DISPLAYS

RESOURCES

F1-10

1. MCS-80/85 FAMILY USERS MANUAL (Intel, 1979).
2. Zumchak, MICROCOMPUTER DESIGN AND TROUBLESHOOTING (Howard Sams, 1982).
3. Leventhal & Walsh, MICROCOMPUTER EXPERIMENTATION WITH THE INTEL SDK 85 (Prentice Hall, 1980).
4. Hall, MICROPROCESSOR AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Edition.
5. Bery, MICROPROCESSOR AND HARDWARE INTERFACING & APPLICATIONS (Merrill, 1984).
6. PERIPHERAL DESIGN HANDBOOK (Intel, 1981).
7. Goody, THE INTELLIGENT MICROCOMPUTER (SRA, 1982).
8. Larsen, Titus, & Titus, 8085A COOKBOOK (Howard Sams, 1982).
9. Titus, Rony, Larsen & Titus, 8080/8085 SOFTWARE DESIGN BOOK I (Howard Sams, 1982).
10. Larsen, Titus, & Titus, 8080/8085 SOFTWARE DESIGN BOOK II (Howard Sams, 1981).

INFORMATION SHEET

F1-10.1

MEMORY

Before we talk about memory, it will be necessary to introduce some terms associated with memory:

Address decoder

A device that decodes the memory address presented on the address bus by the microprocessor to select memory devices.

Access time

The time required for a memory component to produce the addressed information at its output pins.

Completely Decoded

When all of the possible memory addresses are specified.

DRAM (Dynamic RAM)

A memory device that stores information for a brief period of time, usually about 2 ms.

Memory map

A drawing of the proposed structure of the memory system.

Nonvolatile

Describes a memory device able to retain data even when power is removed from the system.

Refresh

The act of periodically rewriting data in a dynamic RAM.

RAM (static)

A device that stores information as long as power is applied to the system.

EPROM

An erasable type of permanent read only memory. This type of ROM is field programmable.

EEPROM

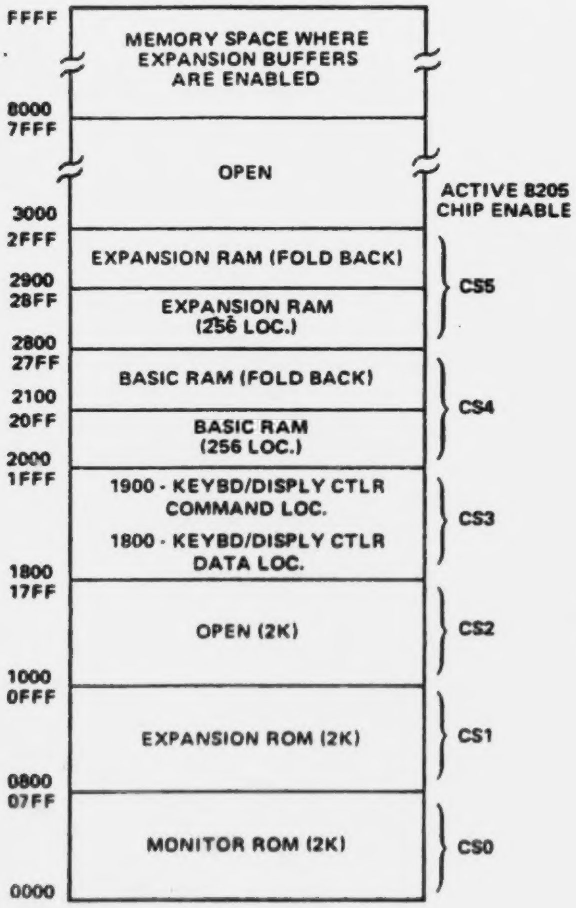
An electrically erasable type of permanent read only memory, which can sometimes be used as volatile memory. The program can erase and reprogram the memory.

This learning guide will be concerned with concentrating on RAM, EPROM, and DRAM, static RAM, and EPROM. If you were to add more RAM to your trainer you would have to be concerned with several items, namely, timing and system decoding. System timing relates to the memory's access time. The memory device you select must have a fast enough access time to match the system's timing requirements. This information is always included with the data for the memory device.

Another consideration is system decoding, which refers to the systems memory map. This information will be found in the operation or user's manual for your system. Figure F1-10.1-1 an example of a memory map and Figure F1-10.1-2 is an example of the system decoder and memory. If you study the memory map you will see the memory is diagrammed from hex 0000 to hex FFFF, which is 64K of memory. You will recall that this is all the memory that a 16-bit memory address is able to address. Notice, there are areas marked for expansion and some marked expansion (fold back). This is something to pay attention to, because the areas marked as (fold back) have not been decoded, and would require further decoding. The area marked as expansion with no mention of fold back have been decoded and could be used without any further addition of decoding circuitry. On this particular system there is a place for two separate 256-byte additions. You should also note the location of the system's monitor in ROM at locations 0000 hex to 07FF hex.

Actually, there is a lot of area open for memory expansion on this system.

Now, take a look at the schematic of the address decoder and memory. This particular system uses a 3 by 8 decoder and four large-scale integrated circuit memory chips, two RAM and two ROM chips. Also, note that these are special devices which have input/output ports as part of their circuitry. If you look closely at the decoder, you will see that it is only decoding 5 of the 16 address lines. Also, look at the decoder's outputs; only 5 of 8 are used. It appears, that it would be a fairly straightforward task to add memory to this system. Take some time and see if you can figure what address must be put on the address lines to select a particular memory device. Also, see if you can figure the output/input port decoding for each of the A and B ports illustrated on each device (hint: study the data sheets for an 8355 ROM and an 8155 RAM).


FFFF
MEMORY SPACE WHERE EXPANSION BUFFERS ARE ENABLED
8000
7FFF
OPEN
3000
ACTIVE 8205 CHIP ENABLE
2FFF
EXPANSION RAM (FOLD BACK)
2900
28FF
EXPANSION RAM (256 LOC.)
CS5
2800
27FF
BASIC RAM (FOLD BACK)
2100
20FF
BASIC RAM (256 LOC.)
CS4
2000
1FFF
1900 - KEYBD/DISPLY CTLR COMMAND LOC.
1800 - KEYBD/DISPLY CTLR DATA LOC.
CS3
1800
17FF
OPEN (2K)
CS2
1000
0FFF
EXPANSION ROM (2K)
CS1
0800
07FF
MONITOR ROM (2K)
CS0
0000

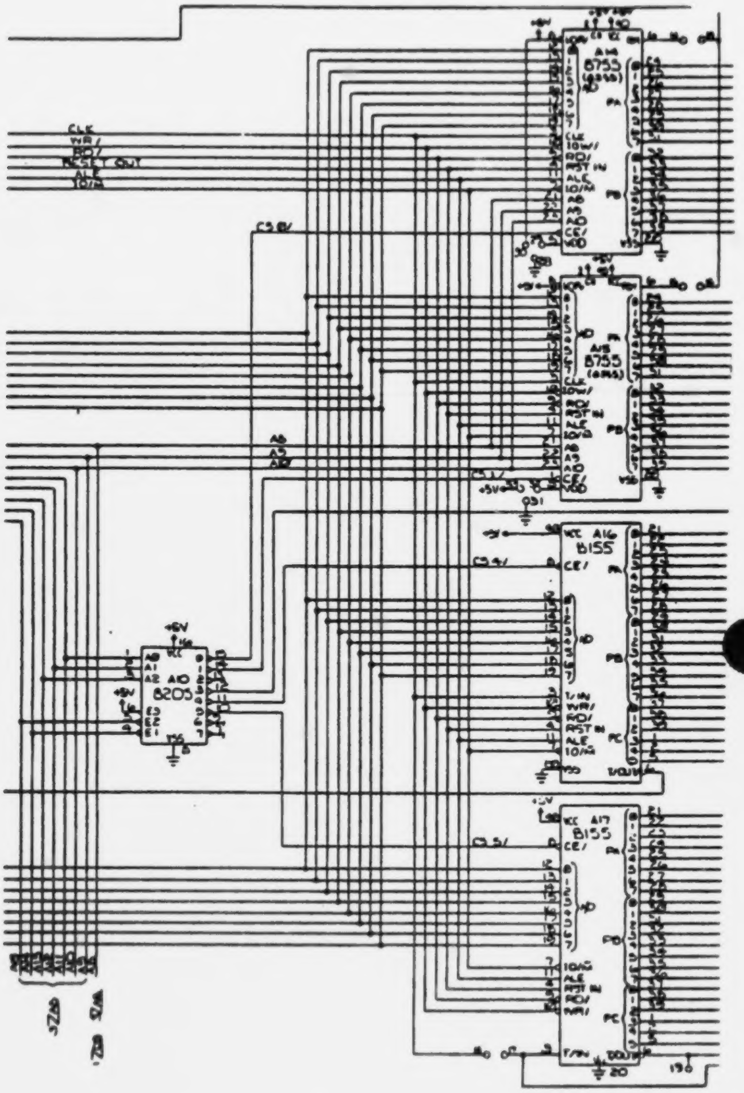

CLK
WR/
RD/
RESET OUT
ALE
IO/M
CS0/
A14 8755
A15 8755
CS1/
A8
A9
A10
A10 8205
+5V
A16 8155
CS4/
A17 8155
CS5/
PA
PB
PC

Figure F1-10.1-1

Figure F1-10.1-2

Let's take a look at a static RAM chip to get an understanding of its circuitry and operation. The device is an 1024 x 8-bit unit. This means that it is arranged internally as 1k of 8-bit data locations. This type of RAM is sometimes referred to as byte-wide. It has multiplexed address and data lines, so it can be directly connected to a microprocessor like the 8085. You will also notice the standard chip-select, read, write and chip-enable connections. It is interesting that all of this circuitry is placed in a 18 pin package. The trend in memory devices is more density in smaller packages. All in all, this chip should be fairly easy to interface to a small system like your microprocessor trainer or a small system used for control applications.

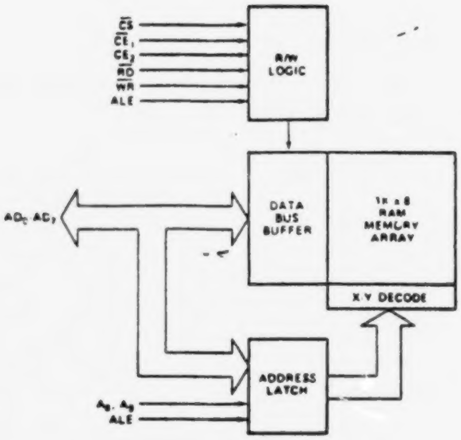


Figure F1-10.1-2

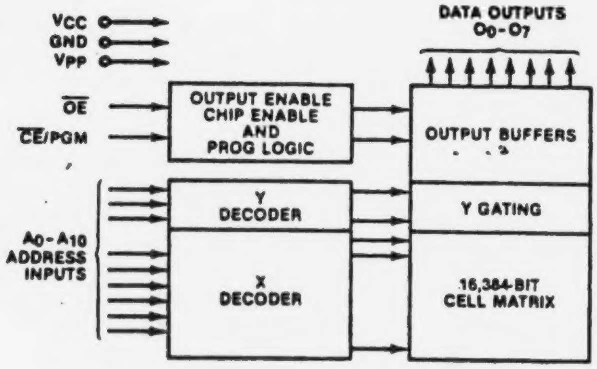
Dynamic RAM packages are packed with even more memory than the static unit you saw in Figure F1-10.1-2. When people talk about 64k memory and 256k memory chips they are talking about dynamic memory devices. Dynamic RAM has the advantage of packing more memory, but is has the disadvantage of being harder to interface or use, because it must constantly be refreshed. Unlike static RAM which will retain data for as long as the power is on, dynamic RAM must have its memory refreshed about every 2 milliseconds. To do this, there must be circuits on the board to access each cell and refresh the contents of each cell. Fortunately, there are large integrated circuits made today that service the need of large banks of dynamic RAM, making the job of access and refresh much easier.

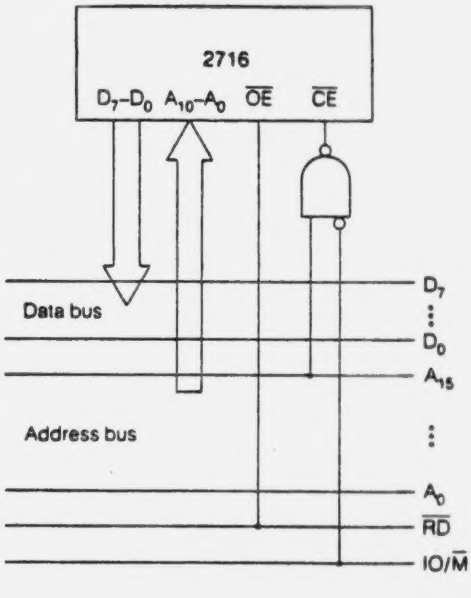
Another type of memory we need to look at is the permanent, nonvolatile memory. This type of device comes in several forms.

ROM is short for read only memory. This type of memory is read from, but not written in. It is used where the information put in must be remembered even after the power is turned off. Plain ROM is usually mask programmed at the factory, and can never be changed. This type of permanent memory is fine for large production runs but not where memory might change during or after development. For permanent memory that might need to be changed, we use EPROM, electrically programmable read only memory. This type of memory can be programmed with voltage pulses and then be erased in strong UV light; hence, erasable programmable memory.

A family of this type of memory is the 2700 series. The 2716 is a 16K EPROM, organized 2K x 8. The 2732 is organized 4K x 8. The 2758 is organized 1K x 8. The 2716 is a popular unit, because it comes in a variety of access times, operated from a single +5 volts, enjoys low power dissipation, and is easy to program. There are many devices on the market which will allow you to field program these devices from a personal computer, a very attractive feature for small system development. Shown below is a block diagram of a 2716 and its connection to a 8085 processor.

Only a small portion of information pertaining to memory devices and their connection to a microprocessor has been included in this learning guide; therefore, it is strongly suggested that you do extensive reading in this area. The more knowledge you possess about this subject the easier it will be for you to interface and troubleshoot memory devices.


VCC
GND
VPP
$\overline{OE}$
$\overline{CE}$/PGM
A0-A10 ADDRESS INPUTS
DATA OUTPUTS O0-O7
OUTPUT ENABLE CHIP ENABLE AND PROG LOGIC
OUTPUT BUFFERS
Y DECODER
Y GATING
X DECODER
16,384-BIT CELL MATRIX


2716
D7-D0
A10-A0
$\overline{OE}$
$\overline{CE}$
Data bus
D7
D0
A15
Address bus
A0
$\overline{RD}$
IO/$\overline{M}$

ACTIVITY SHEET

F1-10.2

MEMORY

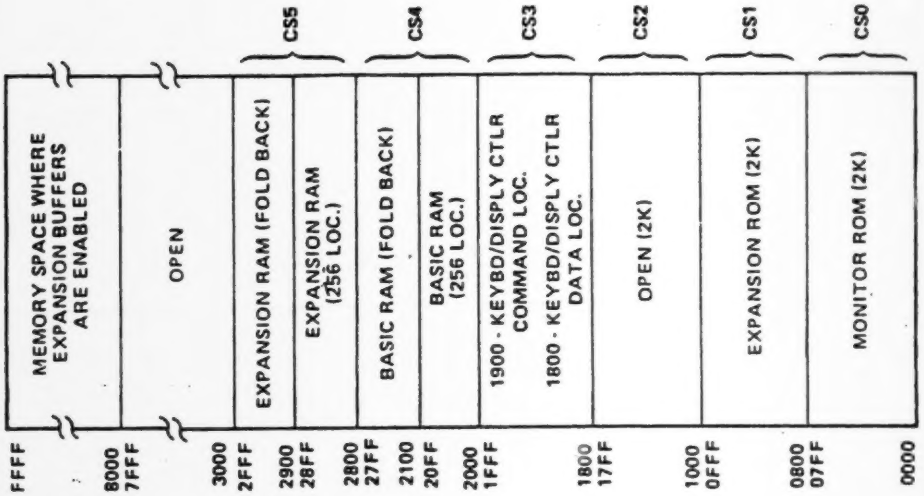
On a separate sheet of paper complete all of the activities called for:

1. Draw a memory map of your trainer's memory system.
2. Draw the interface of an 8185 static RAM to your trainer's memory system. Place it at a clear decoded position (between 3000H and 7FFF H).
3. Draw the interface of a 2716 EPROM to your trainer's memory system. Locate it at memory locations 1000H to 17FFH.

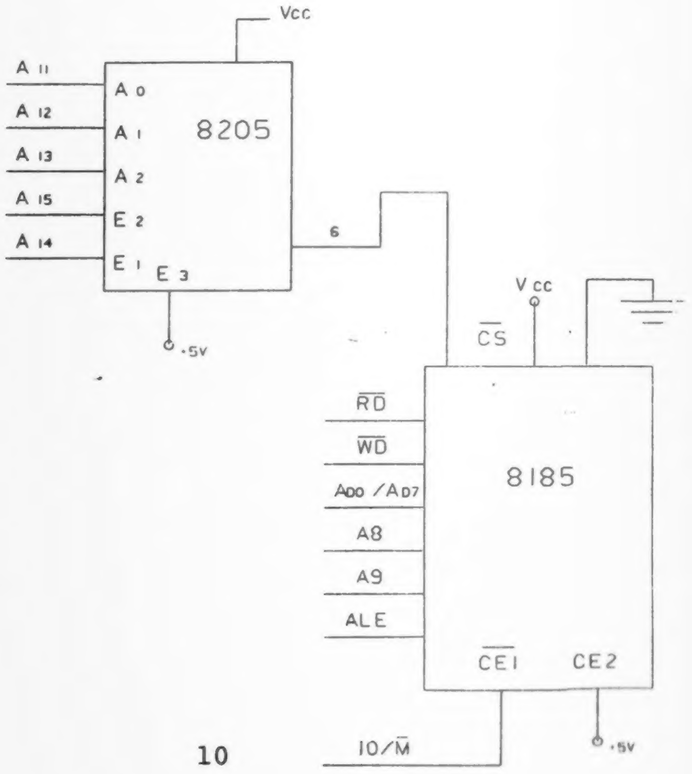
ACTIVITY SHEET F1-10.2

ANSWER SHEET

1. Map might appear as shown.

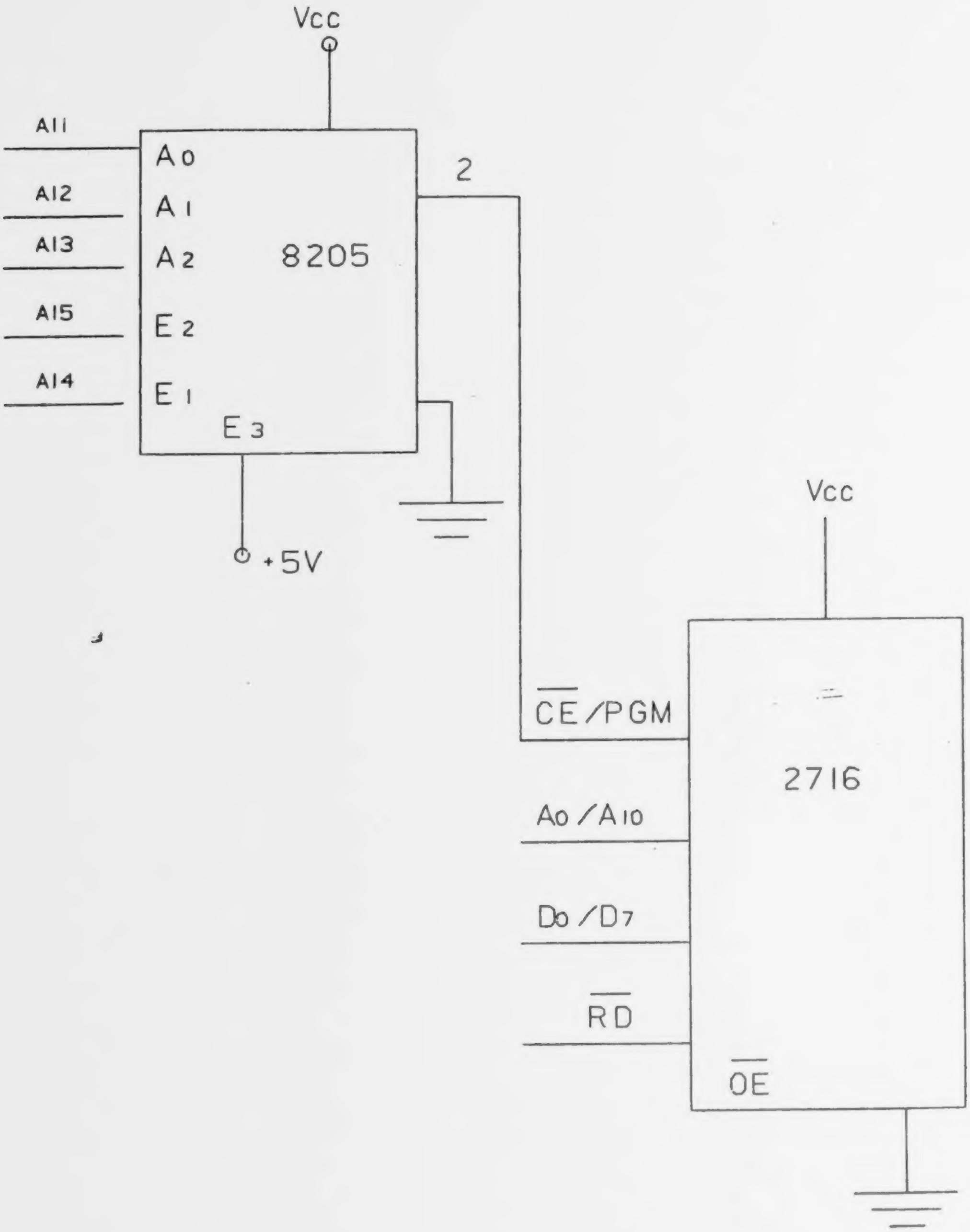

CS5
CS4
CS3
CS2
CS1
CS0
MEMORY SPACE WHERE EXPANSION BUFFERS ARE ENABLED
OPEN
EXPANSION RAM (FOLD BACK)
EXPANSION RAM (256 LOC.)
BASIC RAM (FOLD BACK)
BASIC RAM (256 LOC.)
1900 - KEYBD/DISPLY CTLR COMMAND LOC.
1800 - KEYBD/DISPLY CTLR DATA LOC.
OPEN (2K)
EXPANSION ROM (2K)
MONITOR ROM (2K)
FFFF
8000
7FFF
3000
2FFF
2900
28FF
2800
27FF
2100
20FF
2000
1FFF
1800
17FF
1000
0FFF
0800
07FF
0000

2. Interface may appear as illustrated.


Vcc
A 11
A 12
A 13
A 15
A 14
A 0
A 1
A 2
E 2
E 1
E 3
8205
6
+5V
Vcc
CS
RD
WD
AD0 /AD7
A8
A9
ALE
8185
CE1
CE2
IO/M
+5V

ANSWER SHEET

3. Interface may appear as illustrated.


Vcc
A11
A12
A13
A15
A14
A0
A1
A2
E2
E1
E3
8205
2
+5V
Vcc
$\overline{CE}$/PGM
2716
A0/A10
D0/D7
$\overline{RD}$
$\overline{OE}$

INFORMATION SHEET

F1-10.3

7-SEGMENT DISPLAY INTERFACE

There are several ways to interface 7-segment displays to a microprocessor. One approach is to use a hardware interface. Figure F1-10.3-1 is an example of a single digit hardware connection. The advantage of this method is simplicity in software implementation, but the disadvantage is the inflexibility of design that is built in. A second approach is through software, which provides little hardware and greater flexibility for design change. The problem with this approach is processor time and more complicated software routines. Figure F1-10.3-2 is an example of a software connection, for there are no decoders or latches involved. A third method is a combination of both hardware and software, which is accomplished by using a LSI keyboard and display chip. This particular unit is represented by Figure F1-10.3-3. The choice of which of these methods you might use would depend on the complexity of the task you faced. If you were only adding two digits to the system, then the LSI device would be overkill. However, if you were building a system which needed a multi-key keyboard and six to eight 7-segments, then the 8279 LSI unit would make the job more manageable.

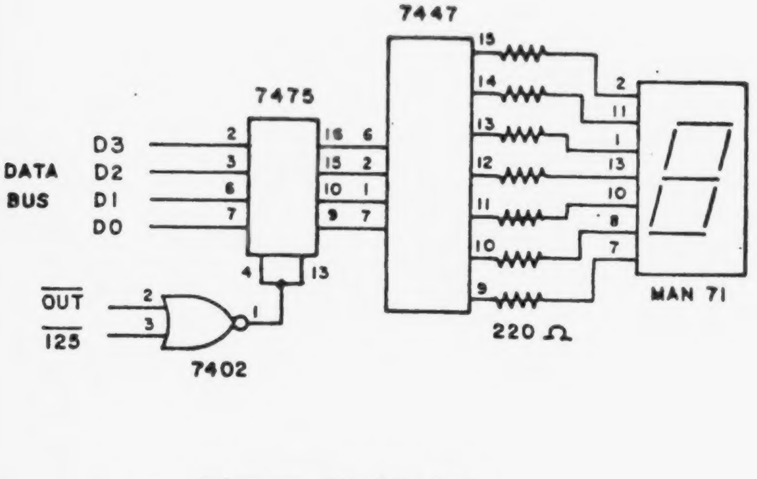


Figure F1-10.3-1

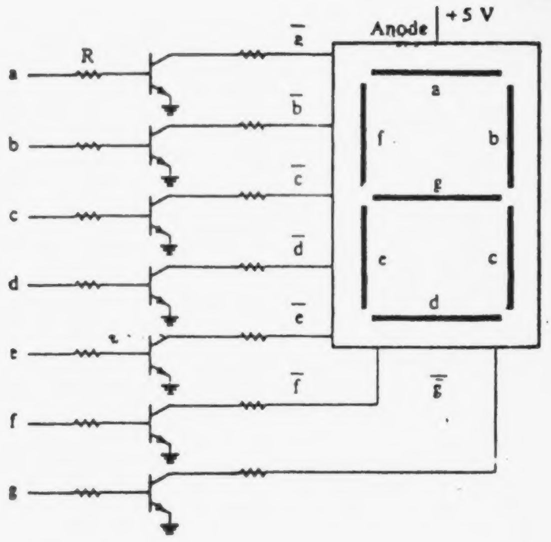


Figure F1-10.3-2

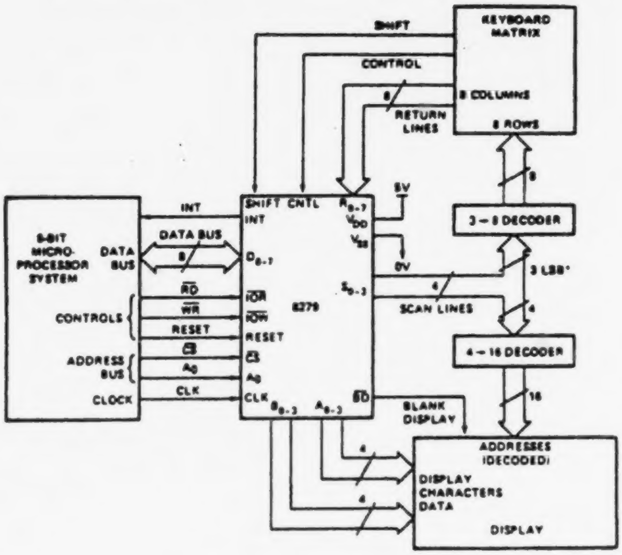

SHIFT
CONTROL
KEYBOARD MATRIX
8 COLUMNS
8
RETURN LINES
8 ROWS
8
8-BIT MICRO-PROCESSOR SYSTEM
DATA BUS
CONTROLS
ADDRESS BUS
CLOCK
INT
DATA BUS
8
RD
WR
RESET
CS
A0
CLK
SHIFT CNTL
INT
D0-7
IOR
IOW
RESET
CS
A0
CLK
B0-3
A0-3
R0-7
VDD
VSS
S0-3
BD
8279
5V
0V
4
SCAN LINES
3 – 8 DECODER
3 LSB'
4
4 – 16 DECODER
16
BLANK DISPLAY
4
4
ADDRESSES (DECODED)
DISPLAY CHARACTERS DATA
DISPLAY

Figure F1-10.3-3

Let's say we have decided to use the software approach to interface two CA 7-segment displays to our trainer. The hardware will be quite simple, and appear like that of Figure F1-10.3-4. The software, will be a bit more complicated. Since we are not using a decoder to change the BCD number to a 7-segment code, we have to take care of that problem with software. This is usually handled by a subroutine, which can be called when the conversion is necessary, and the use of what are called look-up tables. A look-up table is nothing more than a listing of the necessary digit code in sequential memory locations, which is addressed by the digit to be converted. That is, the digit for conversion is added to the memory of the first number in the table and causes the memory pointer to move to the proper code for that number. Figure F1-10.3-5 shows an example of a conversion subroutine using a look-up table.

A flowchart for a subroutine to multiplex two 7-segment displays is illustrated in Figure F1-10.3-6. Study the logic of this chart to grasp an understanding of how software can be used to implement hardware in an interface. Notice, the use of software to replace the decoder chips, a delay to replace the use of latches, and digit select software to replace the multiplexer. It should be clear that software design will give you a greater flexibility, for the change from 2 digits to 4 digits would only require minor changes in both hardware and software.

The examples included in this guide are by no means all the ways possible to interface displays. Look through text and electronic magazines and you will come across numerous ways of interfacing 7-segment displays and many software and hardware approaches for connecting to the microprocessor.

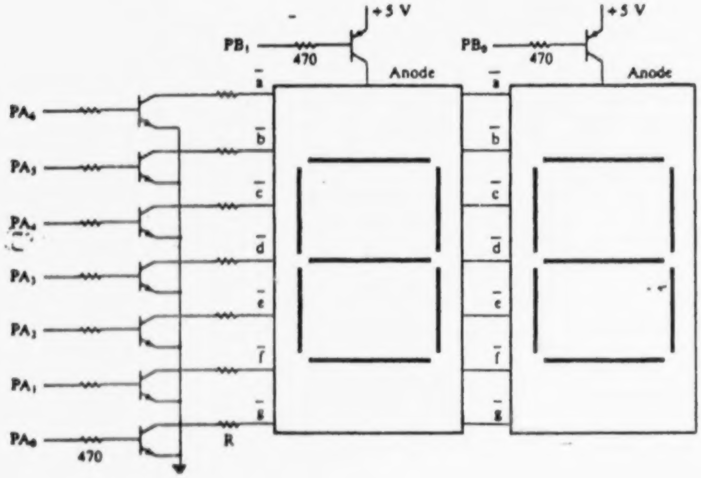

+5 V
+5 V
PB1
PB0
470
470
Anode
Anode
PA6
PA5
PA4
PA3
PA2
PA1
PA0
470
R
a
b
c
d
e
f
g
a
b
c
d
e
f
g

Figure F1-10.3-4

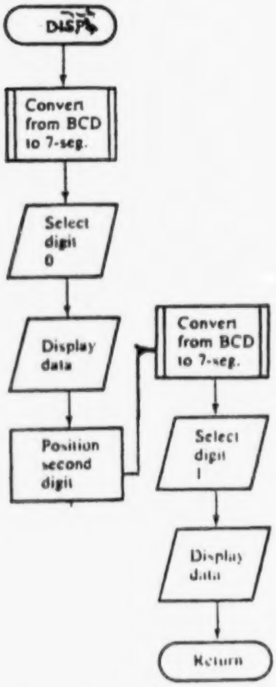
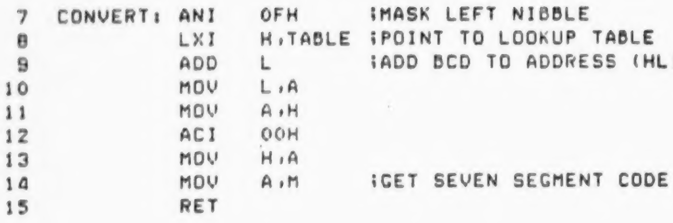

DISP
Convert from BCD to 7-seg.
Select digit 0
Display data
Position second digit
Convert from BCD to 7-seg.
Select digit 1
Display data
Return

Figure F1-10.3-6



```
CONVERT: ANI    0FH      ;MASK LEFT NIBBLE
         LXI    H,TABLE  ;POINT TO LOOKUP TABLE
         ADD    L        ;ADD BCD TO ADDRESS (HL)
         MOV    L,A
         MOV    A,H
         ACI    00H
         MOV    H,A
         MOV    A,M      ;GET SEVEN SEGMENT CODE
         RET
```

Figure F1-10.3-5

ACTIVITY SHEET

F1-10.4

7-SEGMENT DISPLAY INTERFACE

On a separate sheet of paper complete all of the activities called for:

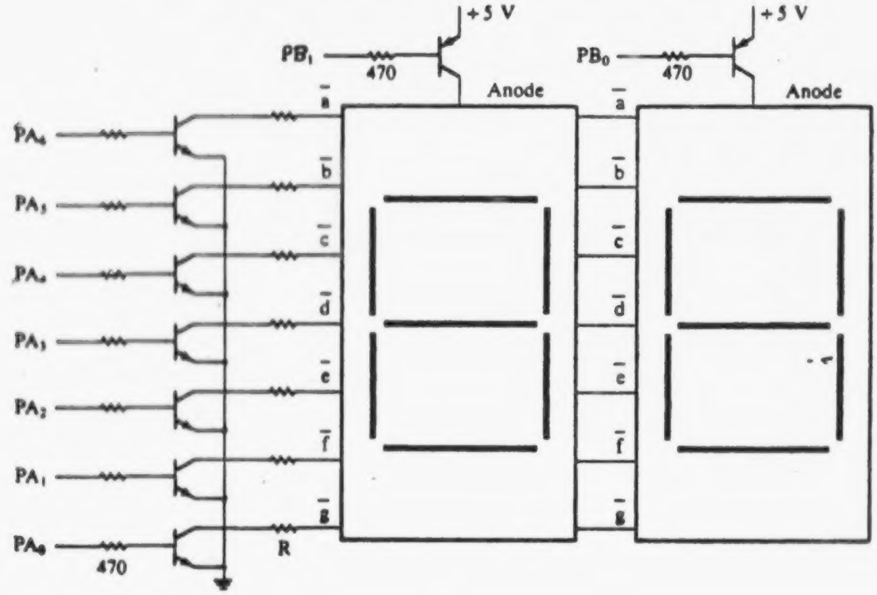
1. Draw the hardware interface to connect two multiplexed 7-segments CA displays to your microprocessor trainer.

2. Write the software to interface these two digits to your microprocessor.

ACTIVITY SHEET F1-10.4

ANSWER SHEET

1. Hardware interface may appear as illustrated below:


+5 V
+5 V
PB_1
470
PB_0
470
Anode
Anode
$\overline{a}$
$\overline{b}$
$\overline{c}$
$\overline{d}$
$\overline{e}$
$\overline{f}$
$\overline{g}$
$\overline{a}$
$\overline{b}$
$\overline{c}$
$\overline{d}$
$\overline{e}$
$\overline{f}$
$\overline{g}$
PA_6
PA_5
PA_4
PA_3
PA_2
PA_1
PA_0
470
R

2. Software interface may appear as follows:

```
ADDR. OPCODE    LABEL    MNEMONIC        COMMENTS
                PORTA    EQU 21h         ;Port A address
                PORTB    EQU 22h         ;Port B address
                STAT     EQU 20h         ;Status
2000  31C220    SETUP:   LXI SP,20C2h    ;Load Stack Pointer
2003  3E03               MVI A,3         ;Initialize ports A & B
2005  D320               OUT  STAT       ;set status register 20
2007  06FF               MVI B,FFh       ;Set a number of times the
2009  3E77      LOAD:    MVI A,77h       ;Load data for display
200B  C35020             JMP DISPLY      ;Jump to program start

2050  F5        DISPLY: PUSH PSW         ;save accumulator
2051  CD9020             CALL CONV       ;convert BCD to 7-seq code
2054  D321               OUT PORTA       ;Out first 7 to ports A
2056  3E02               MVI A,2         ;Select digit 0
2058  D322               OUT PORTB       ;Out to port B
205A  CD8020             CALL DELAY      ;Call delay subroutine
205D  F1                 POP PSW         ;restore accumulator
205E  0F                 RRC             ;Rotate nibble to right
205F  0F                 RRC
2060  0F                 RRC
2061  0F                 RRC
```

ACTIVITY SHEET F1-10.4 CONT'D.

ANSWER SHEET

```
ADDR.  OPCODE    LABEL     MNEMONIC       COMMENTS
2062   CD9020              CALL CONV      ;convert again
2065   D321                OUT PORTA      ;Out to port A
2067   3E01                MVI A,1        ;Light digit #1
2069   D322                OUT PORTB      ;Out to port B
206B   CD8020              CALL DELAY     ;Call delay routine
206E   05                  DCR B          ;Decrease # times counter
206F   C22920              JNZ LOAD       ;If not zero load again
2072   76                  HLT            ;Halt

2080   23004E    DELAY:    LXI D,4E00h    ;Load delay time
2083   1B        LOOP:     DCX D          ;Pair used for size
2084   7A                  MOV A,D
2085   B3                  ORA E
2086   D28320              JNZ LOOP
2089   C9                  RET            ;Return

2090   E60F      CONV:     ANI 0Fh        ;Start convert routine
2092   21A020              LXI H,TABLE    ;Load table pointer
2095   8D                  ADD L          ;Add BCD to table
2096   6F                  MOV L,A
2097   7C                  MOV A,H        ;Pointer offset by number
2098   CE00                ACI 0
209A   67                  MOV H,A
209B   7E                  MOV A,M        ;Get 7-segment code
209C   C9                  RET            ;Return

20A0             TABLE:    DB  7Eh,30h,6Dh,79h,33h
                           DB  5Bh,5Fh,70h,7Fh,7Bh
```

PROGRAM: ELECTRONICS

TASK: INTERFACING RAM AND DISPLAYS

TASK # F1-10.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ___________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Prepare the software and hardware to perform the interface operations with RAM and display.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 55 minutes and must score at least 8 out of 10 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 55 minutes and must score 8 out of 10 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

INTERFACING RAM AND DISPLAYS

F1-10.5

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required date recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

STUDENT'S SCORE _____

INTERFACING RAM AND DISPLAYS

EXAM F1-10.6

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on memory and 7-segment display interface. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F1-10.6

1. DRAM is short for dual RAM.

   A. True
   B. False

2. DRAM must be constantly refreshed.

   A. True
   B. False

3. 1K byte of RAM in decimal space is ____________ bytes.

   A. 1000
   B. 1024
   C. 1200
   D. 1600

4. 2K byte of ROM in hex space is ____________bytes.

   A. 2000
   B. 17FF
   C. 03FF 0800
   D. 017F

5. A memory map is a diagram of system memory allocation.

   A. True
   B. False

6. A system with memory fold back has been completely decoded.

   A. True
   B. False

7. Static RAM is usually manufactured with higher cell density than DRAM.

   A. True
   B. False

8. A hardware interface of a 7-segment display to a processor is usually the most flexible.

   A. True
   B. False

9. CA is short for common anode.

   A. True
   B. False

10. A software interface for a 7-segment display will usually require a look-up table.

    A. True
    B. False

EXAM KEY 10.6

1. B
2. A
3. B
4. C
5. A
6. B
7. B
8. B
9. A
10. A

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (8085)

F1-11: INTERFACING SWITCHES AND LEDS

TASK: Prepare the software and hardware to reform interface operations with switches and LEDs.

PURPOSE: This learning guide will introduce more software and hardware interfaces, particularly switches and LEDs. After completing this guide, you should understand the software and hardware requirements for a keypad interface to the microprocessor. You should also be aware of other input and output interfaces which can be made to the processor.

OBJECTIVE: Given access to all necessary tools and equipment, you will prepare the software and hardware to perform interface operations with switches and LEDs. To master this task you must score 80% on a performance checklist and 80% on a written exam.

ESTIMATED CLASS TIME: 12 HOURS

INTERFACING SWITCHES AND LED'S

LEARNING STEPS

F1-11

READ: Information sheet F1-11.1 on "Input and Output Interfaces."

READ: Information on input and output interfaces in one or more of the following resources.

COMPLETE: Activity Sheet F1-11.2 on "Input and Output Interfaces."

COMPLETE: Lab performances on input and output interfaces. Contact your instructor.

COMPLETE: A review of all material covered by this learning guide.

COMPLETE: Performance Checklist F1-11.3 on input and output interfaces. Contact your instructor.

COMPLETE: Written Exam F1-11.4 on input and output interfaces. Contact your instructor.

INTERFACING SWITCHES AND LED'S

RESOURCES

F1-11

1. *MCS-80/85 FAMILY USERS MANUAL* (Intel, 1979).
2. Zumchak, *MICROCOMPUTER DESIGN AND TROUBLESHOOTING* (Howard Sams, 1982).
3. Leventhal & Walsh, *MICROCOMPUTER EXPERIMENTATION WITH THE INTEL SDK 85* (Prentice Hall, 1980).
4. Hall, *MICROPROCESSOR AND DIGITAL SYSTEMS* (McGraw-Hill, 1983). 2nd Edition.
5. Bery, *MICROPROCESSOR AND HARDWARE INTERFACING & APPLICATIONS* (Merrill, 1984).
6. *PERIPHERAL DESIGN HANDBOOK* (Intel, 1981).
7. Goody, *THE INTELLIGENT MICROCOMPUTER* (SRA, 1982).
8. Larsen, Titus, & Titus, *8085A COOKBOOK* (Howard Sams, 1982).
9. Titus, Rony, Larsen & Titus, *8080/8085 SOFTWARE DESIGN BOOK I* (Howard Sams, 1982).
10. Larsen, Titus, & Titus, *8080/8085 SOFTWARE DESIGN BOOK II* (Howard Sams, 1981).

INFORMATION SHEET

F1-11.1

INPUT AND OUTPUT INTERFACES

There are many types of input and output interfaces which can be made to a microprocessor, and many different software techniques to implement them. The keyboard or keypad is one of the primary inputs, but not the only type of input used. There are inputs to a microprocessor formed from a bank of sensors sending data in for manipulation and processor action. Input might also come from magnetic tape input, a touch screen, or any of a number of ways.

Since the keypad is one of the primary inputs, let's take a look at a couple of keypad types of input. The first will be a 4 x 4 keypad. The name is based on the arrangement of the switch matrix, 4 keys by 4 keys. Figure F1-11.1-1 is an illustration of the hardware required for the interface. The keyboard scan and debounce is taken care of by software, unlike some interfaces which would take care of these tasks with hardware. Scan is the process of "looking" for a closed key (one that has been pressed) and debouncing is the process of reacting to only one closure. These two tasks, plus decoding, can be accomplished in hardware or in software. The trade-offs are like those of the 7-segment display; what you do not have in hardware must be made up in software.

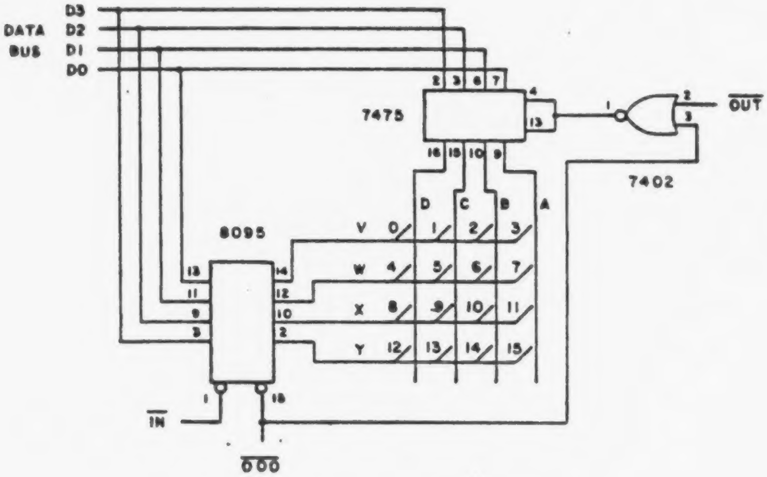

DATA BUS
D3
D2
D1
D0
2
3
6
7
4
13
7475
16
15
10
9
$\overline{\text{OUT}}$
1
2
3
7402
D
C
B
A
8095
V
W
X
Y
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
13
11
9
3
14
12
10
2
1
15
$\overline{\text{IN}}$
$\overline{\text{OOO}}$

Figure F1-11.1-1

INFORMATION SHEET F1-11.1 CONT'D.

An assembly language listing of the software interface for this keypad is illustrated in below. It is apparent, that what is not present in hardware has to be implemented in software.

This subroutine scans a matrix keyboard that is arranged as four rows of four keys, a 4x4 matrix. In addition, instructions have been added to the subroutine to debounce the keys.

```
KEYSCN:   MVI D,03h     ;Load D with the code for the
                        ;first key that can be sensed.
          MVI B,FEh     ;Load B with the word that is used to
                        ;activate one row of keys at a time
NXTGRP:   MOV A,B       ;Get the test word
          OUT 00h       ;and output it to the keyboard
          RLC           ;Rotate the test word left one bit,
          MOV B,A       ;and then save it in B.
          IN  00h       ;Input the data from the four
                        ;rows of keys.
          ANI 0Fh       ;Save only the four LSB's which contain
                        ;the row data.
          CPI 0Fh       ;See if any keys are pressed by
                        ;comparing 017 (0f) to the input word.
          JNZ NXTKEY    ;A key is pressed in this row, so
                        ;determine which key it is.

          DCR D         ;No key are pressed in the tested row,
          MOV A,D       ;so decrement the key word by one and
          CPI FFh       ;see if all four rows have been tested.
          JNZ NXTGRP    ;Not all four rows have been tested,
                        ;so test another row.

          JMP KEYSCN    ;all the rows have been tested and
                        ;no keys are pressed, so keep looking.

NXTKEY:   Call DELAY    ;A key is pressed, so execute the
                        ;Delay subroutine for 10 MS.

AGAIN:    RCC           ;Rotate the row data into the carry.
          JNC RELESE    ;Found the key, so wait for it to
                        ;Be released before returning from
                        ;the subroutine.
          PUSH PSW      ;Otherwise, save the PSW on the stack
          ADI 4
          MOV D,A       ;Save the new key code in D.
          POP PSW       ;Pop the PSW off of the stack,
          JMP AGAIN     ;and then try for a zero carry
                        ;again.
```

```
RELESE:   IN 00h         ;Input the data word again.
          ANI 0Fh        ;Save only the four data bits that
                         ;represent four rows of keys    .
          CPI 0Fh        ;Compare this value to the value obtained
                         ;when no keys are pressed (017, HEX 0F).
          JNZ RELESE     ;Jump if a key is still pressed,
                         ;and wait for it to be released.

DELAY:    PUSH PSW       ;Save the PSW on the stack.
          PUSH D         ;Then save register pair D on the stack.
          LXI D,0341h    ;Load register pair D with a count
                         ;of (HEX 0341).
WAIT:     DCX D          ;Decrement the count.
          MOV A,D        ;Move the MSBY to A.
          ORA E          ;OR it with the LSBY.
          JNZ WAIT       ;If the result is nonzero, Jump
                         ;to the DCXD instruction.
          POP D          ;POP D & E off of the stack,
          POP PSW        ;and then pop the PSW off of the stack
          RET            ;and return with the key code in D.
```

Figure F1-11.1-2 is an example of hardware interface to both a keypad and multi-digit display. This design simplifies the software interface requirements.

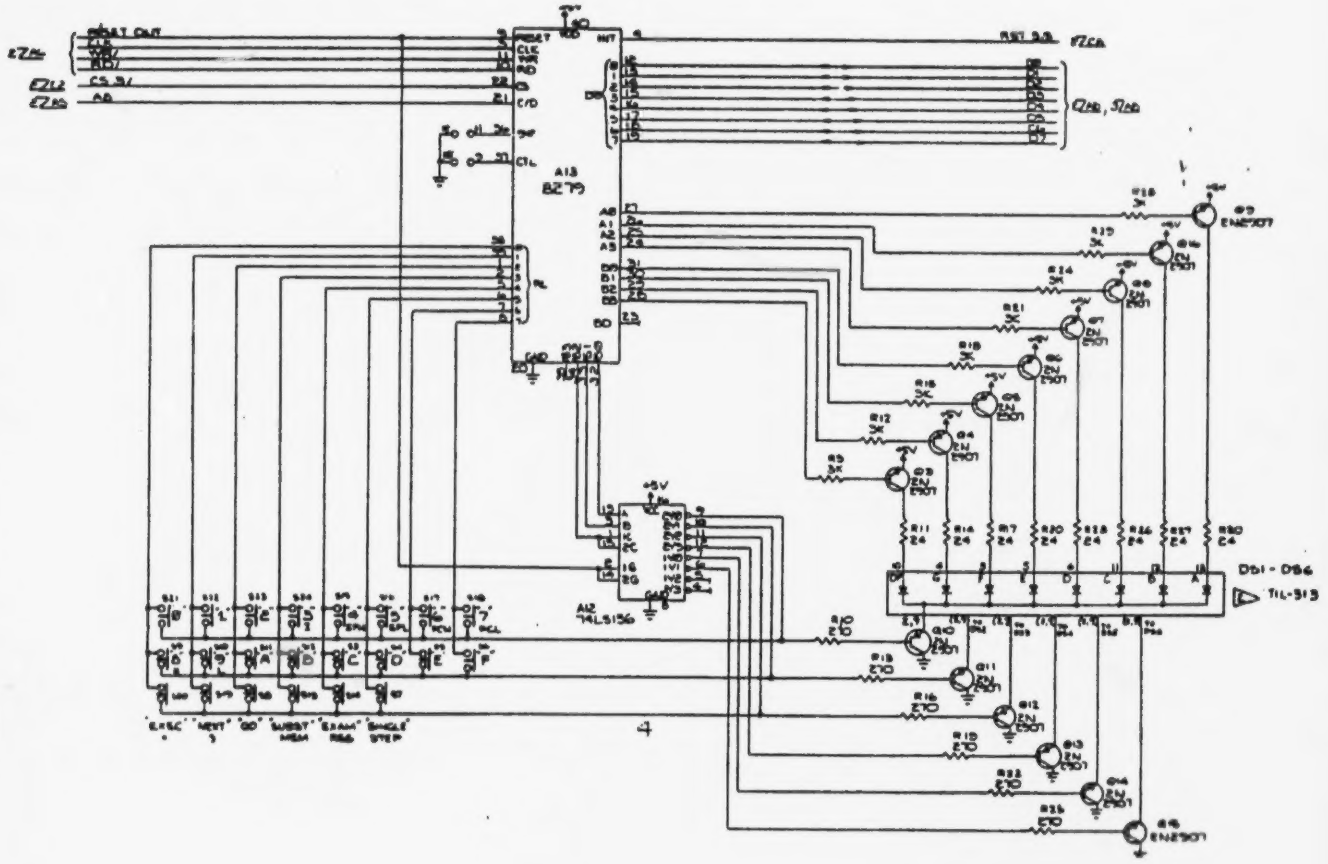

RESET OUT
CLK
CS 31
A0
RESET
CLK
WR
RD
CS
C/D
INT
DB
A13
8279
A0
A1
A2
A3
B0
B1
B2
B3
BD
RL
GND
+5V
A12
74LS156
DS1 - DS6
TIL-313
EXEC
NEXT
GO
SUBST MEM
EXAM REG
SINGLE STEP
2N2907
4

Figure F1-11.1-2

The 8279 has two sections: keyboard and display. The keyboard section can interface to regular typewriter-style keyboard or random toggle or thumb switches. The display section drives alphanumeric displays or a bank of indicator lights. Thus the CPU is relieved from scanning the keyboard or refreshing the display.

This device is designed to directly connect to the microprocessor's bus, so the CPU can program all of its modes of operation including the following: scanned keyboard with different encoding and decoding schemes; key debouncing, and 2-key lockout or N-key rollover; scanned sensor matrix, strobed input; 8- or 16-character multiplexed display. And many more which can be found in the chip's data manual. The main advantage of this type of interface is flexibility and software implementation. Mass production of these special LSI chips has brought their cost down to a range near the discrete chip level, and even cheaper when flexibility is taken into consideration. Take some time to investigate these special interface devices; you will be amazed at the flexibility they offer and the ease of interfacing they bring to a design.

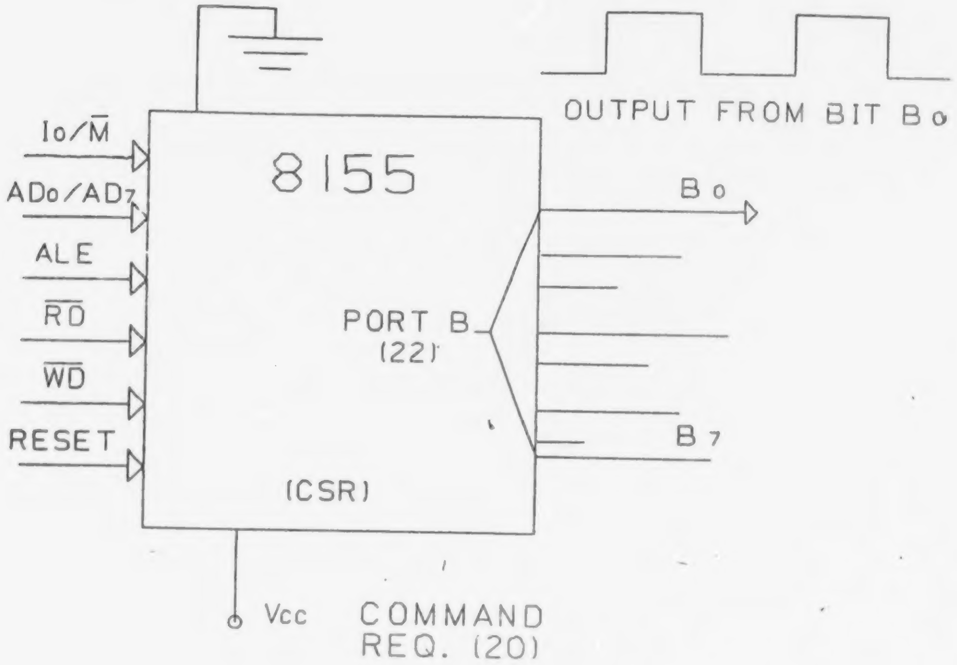
As mentioned earlier in this guide, not all input is from a key switch. Many times the input from a port is information from a sensor which has had its analog signal changed to an acceptable digital signal. This data must be taken into the processor, placed in an input subroutine and acted on in whatever fashion necessary. In other learning guides we will be dealing with input from analog-to-digital converters.

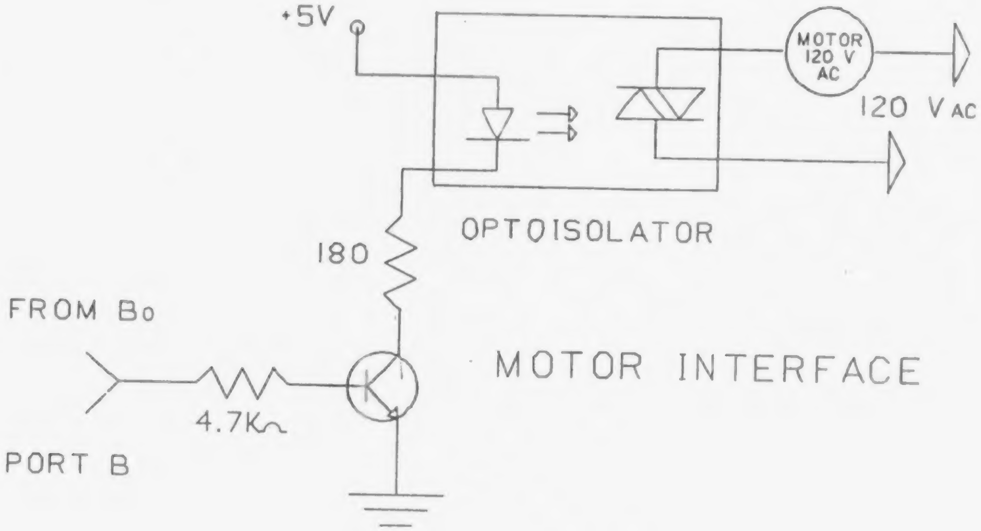
Before we leave the area of input, it might be wise to mention using the keypad of your microprocessor trainer for input. No matter what trainer you are using, it will have some sort of monitor program which allows you to enter data from a set of keys. Usually the data you enter is displayed on the trainer's display, and no more use is made of it; however, there are many times you might need to do more with the data than simply display it. There might be a time when the input from that keypad could go directly into the control process of an interface tied to your processor. Find the monitor listing for your trainer in the user's manual, and investigate the key enter subroutine. It will be a subroutine and have a listing like KEYIN, KEBD, KYBD, KYBDIN, or some similar label. Investigate this routine until you understand how it works; in doing this you will have developed a tool you can use to increase your usage of the microprocessor trainer.

Now let us turn our attention to output devices, particularly output ports and the many things we can tie to them. When we output data to a port we are usually looking for some sort of reaction to that data, like a visual indication (LED on), or the operation of some device, like a motor, being turned on or off. If we want to maximize our use of these output devices, we need to have a good understanding of their interface to the real world.

An introduction to programmable interface chips has been provided earlier in learning guides. Two of the units introduced were the 8155 and the 8255, both of which are programmable from the CPU's software. The 8255 could be programmed to have its ports setup as input or output; it could also have each individual bit in a port programmed to be an input or an output. The illustration which follows demonstrates one of the many ways in which these devices can be used with a microprocessor. The software for this interface is also listed, and could be altered slightly to allow a change in the hardware interface, without any physical changes in that hardware. Study this interface, and see if you could make software changes to cause the hardware to do something different.

MOTOR CONTROL INTERFACE TO MICROPROCESSOR, TIME ON AND TIME OFF CONTROLLED BY SOFTWARE:


OUTPUT FROM BIT B_0
$IO/\overline{M}$
AD_0/AD_7
ALE
$\overline{RD}$
$\overline{WD}$
RESET
8155
B_0
PORT B
(22)
B_7
(CSR)
Vcc
COMMAND
REQ. (20)


+5V
MOTOR
120 V
AC
120 V_{AC}
OPTOISOLATOR
180
FROM B_0
4.7KΩ
PORT B
MOTOR INTERFACE

INFORMATION SHEET F1-11.1 CONT'D.

Software interface for motor time on/off control

```
ADDR. OPCODE    LABEL     MNEMONIC        COMMENTS
                STATUS    EQU 20h         ;Status port
                PORT      EQU 22          ;Output port

2000   3E02     START:    MVI A,2         ;Set up command status
2002   D320               OUT STATUS      ;Output command status
2004   3E01               MVI A,1         ;Turn bit 0 (on)
2006   D322               OUT PORT        ;out to port 22
2008   060A               MVI B,0Ah       ;set up delay time
200A   CD5020             CALL DELAY      ;Call delay routine
200D   3D       LOOP:     DCR A           ;Decrement accumulator
200E   D322               OUT PORT        ;Output to port
2010   060B               MVI B,0Bh       ;time off code, 5.5 sec.
2012   CD5020             CALL DELAY      ;call delay routine again
2015   C3                 JMP LOOP        ;jump back to turn it on
```

Delay subroutine at 2050:

```
2050   F5       DELAY:    PUSH PSW        ;save the flags and a
2051   11FFFF   CONT:     LXI D,FFFFh     ;load a pair with
                                          ;FFFF highest count
2054   1B       DOWN:     DCX D           ;start down count
2055   7A                 MOV A,D         ;put D in the accum.
2056   B3                 ORA E           ;OR D to give logic
2057   C25420             JNZ DOWN        ;needed for JMP test
205A   05                 DCR B           ;Decr.loop times by 1
205B   C25120             JNZ CONT        ; not enough,go again
205E   F1                 POP PSW         ;get flags and a
205F   C9                 RET             ;fell thru so return
```

A slight change in software will allow change in hardware (motor) operation. This is one of the nice things about software interfaces; they are easy to change.

ACTIVITY SHEET

F1-11.2

INPUT AND OUTPUT INTERFACES

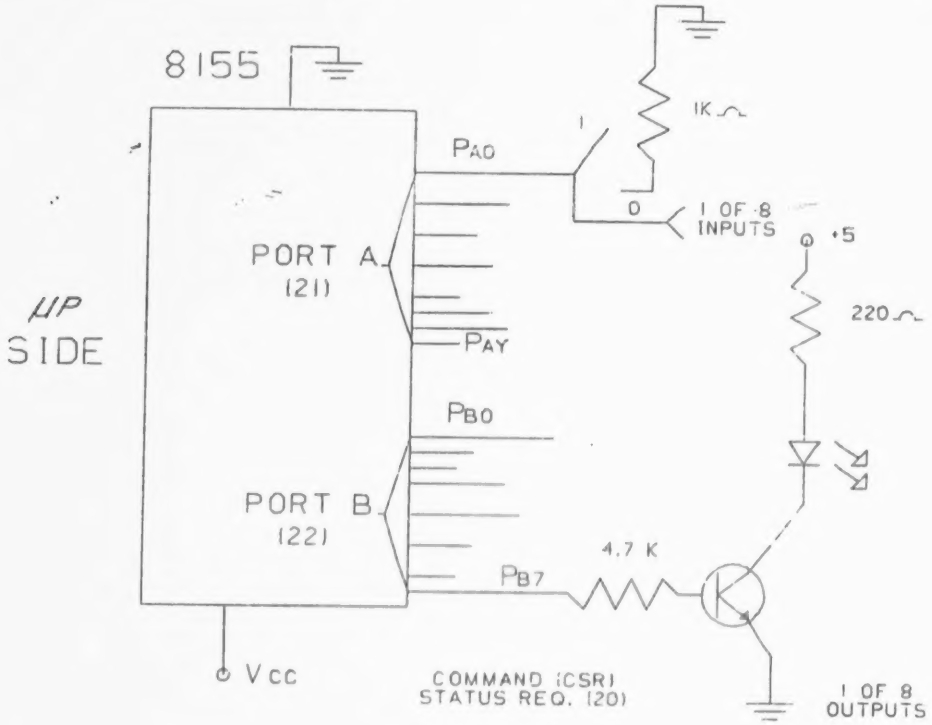
On a separate sheet of paper complete all activities called for.

1. Draw the hardware interface and write the software interface for 8 logic switches as input on port A and 8 LEDs as outputs on port B.

ACTIVITY SHEET F1-11.2

ANSWER SHEET

INTERFACE MAY LOOK LIKE THIS:


8155
1K Ω
1
PA0
0
1 OF 8 INPUTS
+5
PORT A
(21)
μP
SIDE
220 Ω
PAY
PB0
PORT B
(22)
4.7 K
PB7
Vcc
COMMAND (CSR)
STATUS REQ. (20)
1 OF 8
OUTPUTS

SOFTWARE:

```
ADDR. OPCODE    LABEL    MNEMONIC        COMMENTS
                STATUS   EQU 20h
                PORTA    EQU 21h         ;Port A
                PORTB    EQU 22h         ;Port B

2000  3E02               MVI A,2         ;Set port status
2002  D320               OUT STATUS      ;send to CSR
2004  DB21               IN PORTA        ;get byte from A
2006  D322               OUT PORTB       ;put it out to B
2008  76                 HLT             ;Halt
```

PROGRAM: ELECTRONICS

TASK: INTERFACING SWITCHES AND LEDS

TASK # F1-11.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ___________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Prepare the software and hardware to reform interface operations with switches and LED's.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 55 minutes and must score at least 8 out of 10 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 55 minutes and must score 8 out of 10 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

INTERFACING SWITCHES AND LEDS

F1-11.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required date recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

STUDENT'S SCORE _____

1514

INTERFACING SWITCHES AND LEDS

EXAM F1-11.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on interfacing switches and LEDs. Each of the statements is true or false. Place the letter associated with that choice (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F1-11.4

1. All input to a processor is by a keyboard.

   A. True
   B. False

2. Most keyboard debouncing is covered by software.

   A. True
   B. False

3. Debouncing a keyboard refers to ignoring multiple key closures.

   A. True
   B. False

4. The term scanning refers to looking the software over for errors.

   A. True
   B. False

5. All keyboard interfaces are accomplished by hardware.

   A. True
   B. False

6. When using a programmable interface, no initialization is required.

   A. True
   B. False

7. In an 8155 the command status register is used to program the chips ports.

   A. True
   B. False

8. An interface which is primarily software allows for greater flexibility than a hardware interface.

   A. True
   B. False

9. For an 8155, the code MVI A 00, OUT 20, programs both ports A and B to be inputs.

   A. True
   B. False

10. An 8255 can be programmed to have individual bits in the same port programmed for either input or output.

    A. True
    B. False

EXAM KEY F1-11.4

1. B
2. A
3. A
4. B
5. B
6. B
7. A
8. A
9. B
10. A

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (8085)

F1-12: DIGITAL-TO-ANALOG CONVERTERS

TASK: Prepare the software and hardware to interface digital-to-analog converters to the microprocessor.

PURPOSE: This learning guide will introduce you to the process of taking a digital signal, used by the microprocessor, and converting it to an analog signal, which can be used by non-digital devices. After you complete this learning guide, you should understand the operation of digital to analog converters (DACs) and be able to interface them to the microprocessor.

OBJECTIVE: Given access to all necessary tools and equipment, you will prepare the software and hardware to interface digital-to-analog converters to the microprocessor. To master this task you must score 80% on a performance checklist and 80% on a written exam.

ESTIMATED CLASS TIME: 12 HOURS

DIGITAL-TO-ANALOG CONVERTERS

LEARNING STEPS

F1-12

READ: Information Sheet F1-12.1 on "Digital-to-Analog Conversion."

READ: Information on digital-to-analog conversion in one of the following resources.

COMPLETE: Activity Sheet F1-12.2 on "Digital-to-Analog Conversion."

COMPLETE: Lab performances on digital-to-analog conversion. Contact your instructor.

COMPLETE: A review of all material covered in this learning guide.

COMPLETE: Performance Checklist F1-12.3 on digital-to-analog conversion. Contact your instructor.

COMPLETE: Written Exam F1-12.4 on digital-to-analog conversion. Contact your instructor.

DIGITAL-TO-ANALOG CONVERTERS

RESOURCES

F1-12

1. MCS-80/85 FAMILY USERS MANUAL (Intel, 1979).
2. Zumchak, MICROCOMPUTER DESIGN AND TROUBLESHOOTING (Howard Sams, 1982).
3. Leventhal & Walsh, MICROCOMPUTER EXPERIMENTATION WITH THE INTEL SDK 85 (Prentice Hall, 1980).
4. Hall, MICROPROCESSOR AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Edition.
5. Bery, MICROPROCESSOR AND HARDWARE INTERFACING & APPLICATIONS (Merrill, 1984).
6. PERIPHERAL DESIGN HANDBOOK (Intel, 1981).
7. Goody, THE INTELLIGENT MICROCOMPUTER (SRA, 1982).
8. Larsen, Titus, & Titus, 8085A COOKBOOK (Howard Sams, 1982).
9. Titus, Rony, Larsen & Titus, 8080/8085 SOFTWARE DESIGN BOOK I (Howard Sams, 1982).
10. Larsen, Titus, & Titus, 8080/8085 SOFTWARE DESIGN BOOK II (Howard Sams, 1981).

INFORMATION SHEET

F1-12.1

DIGITAL-TO-ANALOG CONVERSION

Many of the devices which a microprocessor has to deal with do not operate on nice little 5-volt logic signals. Many of these devices are analog in nature and can only react to analog voltages and currents. The link between these devices and the processor are analog-to-digital converters (A/Ds) and digital-to-analog converters (D/As). They do what their names imply; that is, they convert an analog signal to a digital signal and vice-versa. This guide will introduce the D/A first, because it is easier to to understand, and because some A/Ds employ as part of their circuitry a digital-to-analog converter.

Basically, a digital-to-analog converter could be thought of as a digitally controlled potentiometer. It produces an analog voltage which is a function of binary inputs multiplied by an analog reference voltage. The binary value put on its inputs by the microprocessor is a binary fraction representing the portion of the full possible output voltage that is to be output. The fractional binary input is multiplied by a reference voltage, which may be either fixed or variable. In finite binary fractions, the most significant bit has a value of 2^{-1}, and the least significant bit is 2^{-n}, where n is the number of bits in the fraction. If all of the bits in the fraction are added, the sum should be close to 1.

The basic structure of most conventional D/A converters involves a network of precision resistors, a set of switches, and some form of level-shifting to adapt the switch drives to the specified logic levels. In addition, the device may contain output-conditioning circuitry, an output amplifier, a reference amplifier, and on-board reference, and on-board buffer register. Figure F1-12.1-1 is a functional block diagram of D/A converter.

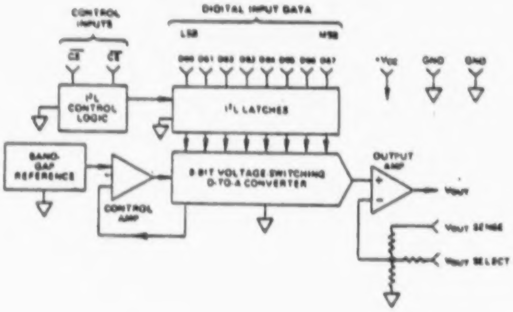


Figure F1-12.1-1

Not all digital-to-analog converters are the same. Linear output is typical, but some devices can produce a digitally-controlled exponential-gain output. The linear output may be current or voltage. The output amplifier may be internal or external. The voltage reference may be internal or external.

There may be one or more feedback resistors provided. The reference input may be for unipolar operation or bipolar operation. The digital data on the inputs may be binary, offset-binary, two's complement, BCD, etc., and the logic representation may be either positive or negative. Also, the power supply connections may be for single or dual supplies.

From the preceding, it should be apparent that there are many features associated with a D/A converter; your best source of information is a manufacturer's data book. Familiarize yourself with such terms as accuracy (absolute and relative), compliance-voltage range, deglitcher, gain, linearity, noise-peak and RMS, offset, resolution, settling time, slew rate, stability, switching time, and timerature coefficients. There are also many excellent reference and texts on the subject of D/A conversion.

Before we conclude, let us take a look at a couple of analog to digital converters and their connections. Figure F1-12.1-2 is MC 1408 series 8-bit converter, with external output amp and voltage reference. This device contains an R-2R ladder network and current-switching logic. Each binary bit controls a switch that regulates the current flowing through the R-2R ladder. If, for example, the binary input of 11000000 (192 base 10) and a 2-mA reference current are applied to the converter, the output current would be equal to 192/256 X 2mA or 1.5 milliamps. The relative accuracy of this device is plus or minus 1/2 of the least significant bit, or 0.19 percent of full scale. The output of the converter is a current equivalent to the product of the reference current and the binary data on the control lines. The current is converted to a voltage through the op amp.

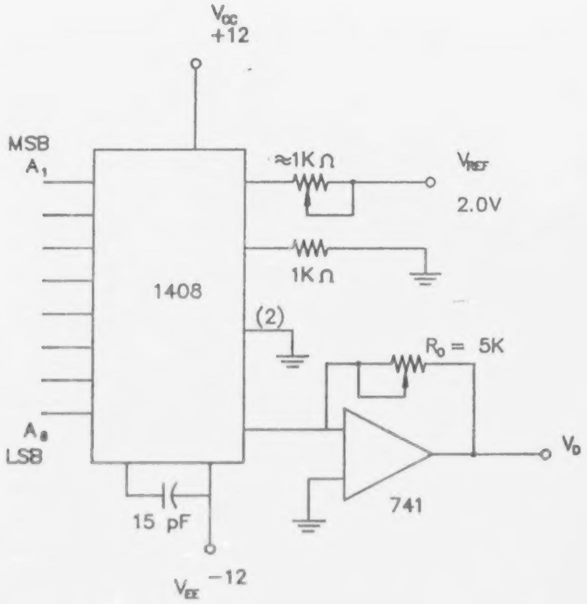


Figure F1-12.1-2

INFORMATION SHEET F1-12.1 CONT'D.

Figure F1-12.1-3 is another D/A converter, but unlike the first it has its reference voltage and output amp built into its circuitry. It also operates off a single power supply, but can be configured to work with bipolar supplies. This unit would be much easier to interface to a microprocessor.

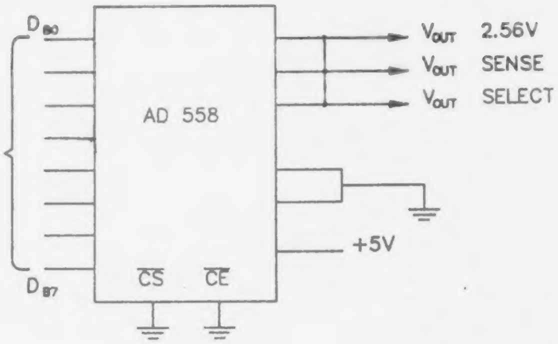

D_{B0}
AD 558
V_{OUT} 2.56V
V_{OUT} SENSE
V_{OUT} SELECT
+5V
$\overline{CS}$
$\overline{CE}$
D_{B7}

Figure F1-12.1-3

ACTIVITY SHEET

F1-12.2

DIGITAL-TO-ANALOG CONVERSION

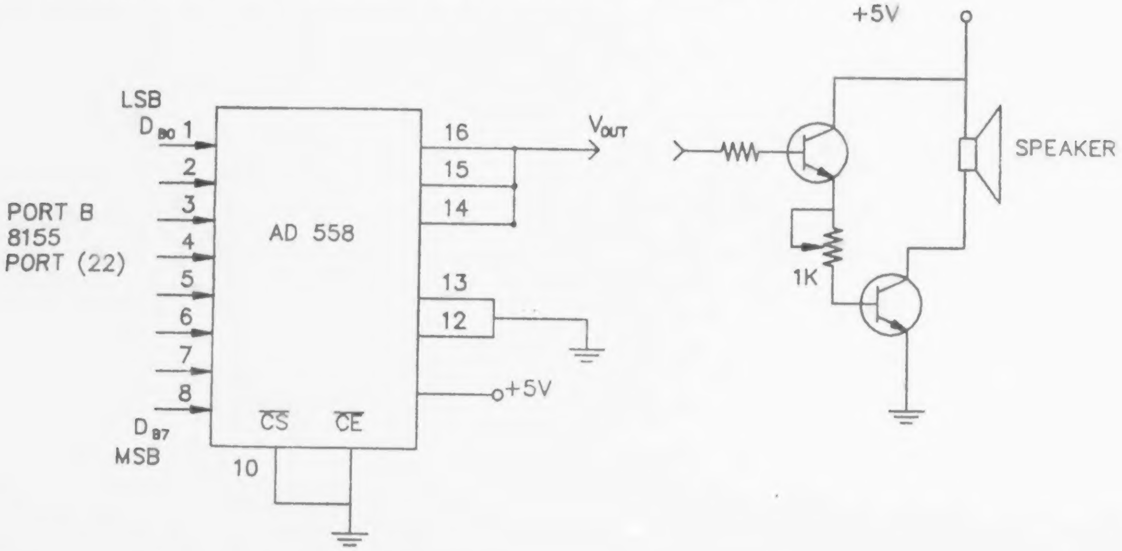
On a separate sheet of paper complete the activities called for.

1. Draw the hardware interface and write the software interface to connect an AD558 digital-to-analog converter to your microprocessor trainer. Write a program which will output different binary numbers to the A/D, and connect the output of the A/D to a small speaker or an oscilloscope so that the digital conversion may be heard or seen.

ACTIVITY SHEET F1-12.2

ANSWER SHEET

YOUR INTERFACE AND PROGRAM MAY APPEAR AS FOLLOWS:


LSB
D B0
1
2
3
4
5
6
7
8
D B7
MSB
PORT B
8155
PORT (22)
AD 558
16
15
14
13
12
10
CS
CE
V OUT
+5V
+5V
1K
SPEAKER

```
ADDR. OPCODE   LABEL    MNEMONIC      COMMENTS
               STATUS   EQU 20h       ;status reg
               PORTB    EQU 22h       ;port B
2000  3E02              MVI A,2       ;set port B for output
2002  D320              OUT STATUS    ;command status reg
2004  3E00              MVI A,00      ;start count at zero
2006  D322     SEND:    OUT PORTB     ;out to port b
2008  F5                PUSH PSW      ;save the 00 value in A
2009  06                MVI B,A0h     ;set delay your choice
200B  11FFFF   LOOP:    LXI D,FFFF    ;start a delay
200F  7A                MOV A,D       ;put D in the accum
2010  B3                ORA E         ;need logic step
2011  C20B20            JNZ LOOP      ;done?
2014  05                DCR B         ;yes
2015  C20B20            JNZ LOOP      ;decrease loop counter
2018  F1                POP PSW       ;get A back from stack
2019  3C                INR A         ;increase counter by 1
201A  C30620            JMP SEND      ;jump back and send to dac
Runs until reset
```

PROGRAM: ELECTRONICS

TASK: DIGITAL-TO-ANALOG CONVERTERS

TASK # F1-12.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ____________

TERMINAL PERFORMANCE OBJECTIVE:

Prepare the software and hardware to interface digital-to-analog converters to the microprocessor.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 55 minutes and must score at least 8 out of 10 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 55 minutes and must score 8 out of 10 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

DIGITAL-TO-ANALOG CONVERTERS

F1-12.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required date recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

STUDENT'S SCORE ______

DIGITAL-TO-ANALOG CONVERTERS

EXAM F1-12.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on digital-to-analog converters. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F1-12.4

1. A device which converts a digital signal to an analog signal is a(n) ______________.

   A. A/D
   B. PIA
   C. D/A
   D. none of the these

2. The term gain refers to ______________.

   A. the ability of an amplifier to reject the effect of voltage applied to both input terms simultaneously.

   B. the analog scale-factor setting that provides the nominal conversion span for a full-scale code change.

   C. a limitation in the rate of change of output voltage.

   D. the time required, following a prescribed data change, for the output of a DAC to reach and remain within a given fraction of the final value.

3. The term resolution refers to ______________.

   A. the ability to provide 2n distinct and different analog output values corresponding to the set of n-bit binary words.

   B. a limitation in the rate of change of output voltage.

   C. the analog scale-factor setting that provides the nominal conversion span for a full-scale code change.

   D. the time required, following a prescribed data change, for the output of a DAC to reach and remain within a given fraction of the final value.

EXAM F1-12.4 CONT'D.

4. The term slew rate refers to ______________.

   A. the ability to provide 2n distinct and different analog output values corresponding to the set of n-bit binary words.

   B. a limitation in the rate of change of output voltage.

   C. the time required, following a prescribed data change, for the output of a DAC to reach and remain within a given fraction of the final value.

   D. the analog scale-factor setting that provides the nominal conversion span for a full-scale code change.

5. If an 8-bit D/A has a voltage span of 10, its approximate resolution is ______________.

   A. 100mA
   B. 20mA
   C. 600mA
   D. 40mA

6. If the same voltage span was used on a 12 D/A, its approximate resolution would be ______________.

   A. 200mA
   B. 20mA
   C. 2mA
   D. .2mA

7. If the binary input to a D/A was 11000000 and if a 2mA reference current was used and if the device had a relative accuracy of + or -1/2 the last significant bit, the output current would be approximately ______________.

   A. 1.50mA
   B. 1.25mA
   C. 1.0mA
   D. .75mA

8. Most D/A converters use ______________.

   A. a weighted resistor network
   B. an R-2R resistor network

9. Which of the following digital coding is used on the inputs of a D/A?

   A. binary
   B. 2's complement
   C. neither of these
   D. both of these

10. Which of the following is not part of the basic structure of a D/A converter?

   A. resistor network
   B. output amp
   C. reference voltage
   D. voltage-to-frequency oscillator

EXAM KEY F1-12.4

1. C
2. B
3. A
4. B
5. D
6. C
7. A
8. B
9. D
10. D

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (8085)

F1-13: ANALOG-TO-DIGITAL CONVERTERS

TASK: Prepare the software and hardware to interface analog-to-digital converters to the microprocessor.

PURPOSE: This guide will familiarize you with the process of converting an analog signal to a digital signal which can then be used by the microprocessor. After you complete this learning guide, you should understand the operation of analog-to-digital converters (ADCs), and be able to interface them to the microprocessor.

OBJECTIVE: Given access to all necessary tools and equipment, you will prepare the software and hardware to interface analog-to-digital converters to the microprocessor. To master this task you must score 80% on a performance checklist and 80% on a written exam.

ESTIMATED CLASS TIME: 12 HOURS

ANALOG-TO-DIGITAL CONVERTERS

LEARNING STEPS

F1-13.1

READ:	Information sheet F1-13.1 on "Analog to Digital Converters."
READ:	Information on analog-to-digital converters from the following resource list.
COMPLETE:	Activity sheet F1-13.2 on "Analog-to-Digital Converters."
COMPLETE:	Lab performances on analog-to-digital converters. Contact your instructor.
COMPLETE:	A review of all material covered in this learning guide.
COMPLETE:	Performance Checklist F1-13.3 on analog-to-digital converters. Contact your instructor.
COMPLETE:	Written Exam F1-13.4 on analog-to-digital converters. Contact your instructor.

ANALOG-TO-DIGITAL CONVERTERS

RESOURCES

F1-13

1. MCS-80/85 FAMILY USERS MANUAL (Intel, 1979).
2. Zumchak, MICROCOMPUTER DESIGN AND TROUBLESHOOTING (Howard Sams, 1982).
3. Leventhal & Walsh, MICROCOMPUTER EXPERIMENTATION WITH THE INTEL SDK 85 (Prentice Hall, 1980).
4. Hall, MICROPROCESSOR AND DIGITAL SYSTEMS (McGraw-Hill, 1983). 2nd Edition.
5. Bery, MICROPROCESSOR AND HARDWARE INTERFACING & APPLICATIONS (Merrill, 1984).
6. PERIPHERAL DESIGN HANDBOOK (Intel, 1981).
7. Goody, THE INTELLIGENT MICROCOMPUTER (SRA, 1982).
8. Larsen, Titus, & Titus, 8085A COOKBOOK (Howard Sams, 1982).
9. Titus, Rony, Larsen & Titus, 8080/8085 SOFTWARE DESIGN BOOK I (Howard Sams, 1982).
10. Larsen, Titus, & Titus, 8080/8085 SOFTWARE DESIGN BOOK II (Howard Sams, 1981).

INFORMATION SHEET

F1-13.1

ANALOG-TO-DIGITAL CONVERTERS

This guide will cover the process of converting a digital word into an analog quantity; that is, we will investigate analog-to-digital converters. As with a D/A converter, the resolution of an A/D converter depends on the number of bits. An 8-bit converter has a resolution of 1 part in 256. There are many types of A/D converters, and in this guide we will be able to cover just a few.

One type of converter is the parallel comparator or "flash" converter. The analog signal to be digitized is applied to all the comparators in parallel; the number of comparators tripped to a high output indicates the amplitude of the analog input voltage. The problem with this type of converter is the number of comparators required to yield any kind of resolution. An N-bit converter would require 2^{n-1} comparators, which means an 8-bit converter would need 256 comparators. On top of this, binary conversion from all of those comparators it would require a tremendous number of AND gates. These problems can be overlooked if speed is the main requirement, because the parallel converter is one of the fastest.

Figure F1-13.1-1 represents a single-slope A/D converter, which uses a ramp generator, comparator, and BCD, or binary counters. To start a conversion cycle the counters and ramp generator are set to zero; then an analog signal is applied to the comparator's plus input. Since the input signal is more positive than the negative input, the comparator outputs a positive voltage and gates on the AND gate, which in turn allows the clock to feed into the counters. This will continue until the feedback on the op amp is such that it will turn the AND gate off, which will stop the count. The count is latched and the contents of the process is the digital representation of the analog signal.

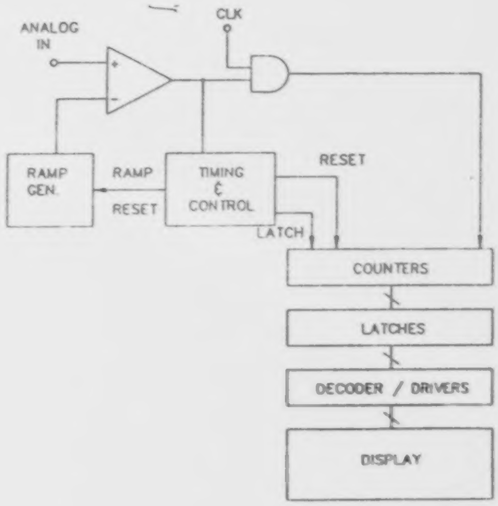


Figure F1-13.1-1

There are also dual-ramp converters, which work on the same basic principle, but with a negative- and positive-going ramp generator (integrator). The unknown voltage is applied to the integrator for a fixed number of counts; the number of counts required for the integrator putout to get back to 0 is directly proportional to the input voltage. The advantages of the dual-slope converter are accuracy and low cost; however, it does have the disadvantage of slow speed. Figure F1-13.1-2 is an example of the dual-slope A/D converter.

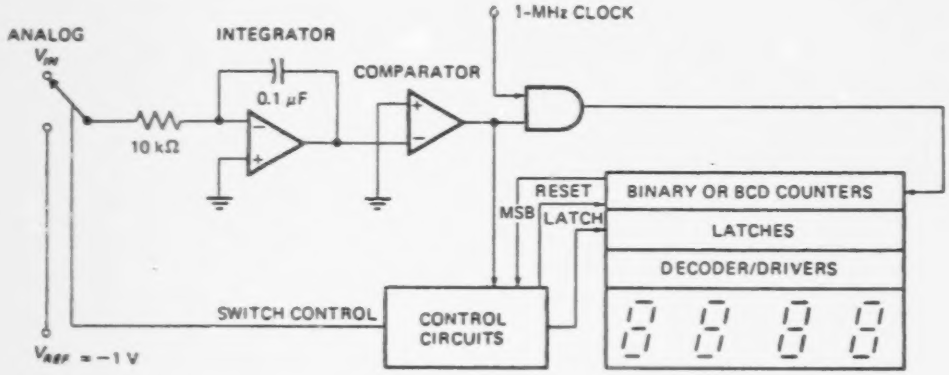

1-MHz CLOCK
ANALOG
V_{IN}
INTEGRATOR
0.1 μF
COMPARATOR
10 kΩ
RESET
MSB
LATCH
BINARY OR BCD COUNTERS
LATCHES
DECODER/DRIVERS
SWITCH CONTROL
CONTROL CIRCUITS
V_{REF} = −1 V

Figure F1-13.1-2

Figure F1-13.1-3 is an example of an A/D converter using a D/A converter as part of its circuitry. The D/A replaces the integrator to make a single-slope type of A/D converter. To start a conversion, the counters are reset and the D/A is zeroed. When a signal is applied to the comparator, its output gates on the counter, which for each clock pulse advances the count and the D/A by one step. When the output from the D/A becomes greater than the input signal to the op amp, the clock is gated off and the final count (binary output) is latched onto the latches. This method is faster than the dual-slope method, but does require the use of a precision D/A converter. The major disadvantage is that for each

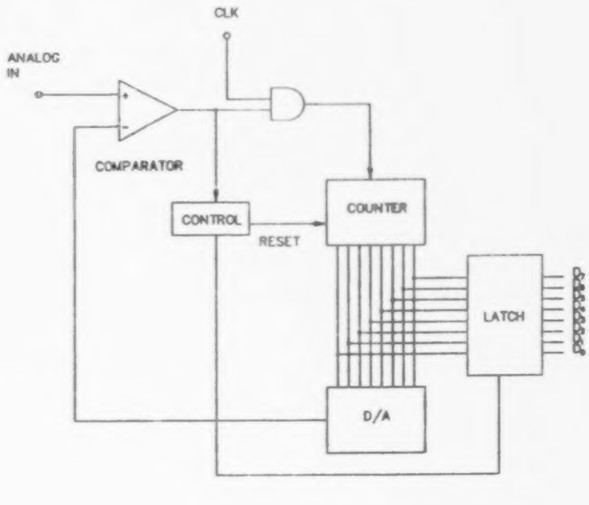

CLK
ANALOG IN
COMPARATOR
CONTROL
RESET
COUNTER
LATCH
D/A

Figure F1-13.1-3

conversion cycle the count has to start at zero and work its way up to the point where the D/A's output matches that of the input signal.

The successive-approximation A/D converter eliminates the problem of every conversion starting at zero. The number of clock pulses for conversion can be equal to the number of bits of resolution; that is, an 8-bit successive-approximation converter will require only 8 clock pulses for conversion, compared to 256 for the counter type. The heart of this converter is the successive-approximation register (SAR), which on the first clock pulse turns out the MSB to feed the D/A converter. It then waits for a signal to see if the comparator was tripped, indicating its output was less than the input signal. If the comparator is tripped, the SAR will retain the MSB bit set to 1; if not the bit will be set to 0. The process will continue down to the least significant bit, trying each bit in turn. It keeps a bit set if the D/A output signal produced is less than the input signal, and resets a bit if the D/A signal output is greater than the input signal. It only requires 8 bits to do one conversion, and when it has finished, it sends out an end-of-conversion (EOC) signal. The successive-approximation A/D converter has the disadvantage of requiring a D/A converter, but makes it up with high speed operation and excellent resolution.

Specifications for A/D converters are like those used for D/A converters; however, the specifications for quantifying error (resolution) and conversion time are two of the more important. There are many types of A/D converters and many applications for their use. Familiarize yourself with the data books from different manufacturers of A/D converters, so that you can develop a greater understanding of their parameters and applications.

ACTIVITY SHEET

F1-13.2

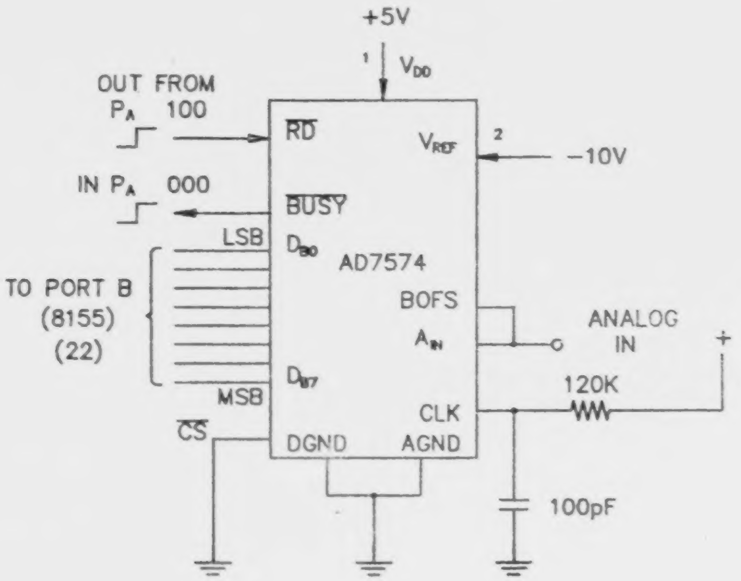
ANALOG-TO-DIGITAL CONVERTERS

1. Draw the hardware interface and write the software interface to connect an A/D converter to your microprocessor trainer. Using a small signal voltage as an input, write a program which will display that analog input as a binary word on an output port.

ACTIVITY SHEET F1-13.2

ANSWER SHEET

Hardware interface may appear as follows:


+5V
1
V_{DD}
OUT FROM
P_A 100
$\overline{RD}$
V_{REF}
2
−10V
IN P_A 000
$\overline{BUSY}$
LSB
D_{B0}
AD7574
TO PORT B
(8155)
(22)
BOFS
ANALOG
IN
A_{IN}
+
120K
D_{B7}
MSB
CLK
$\overline{CS}$
DGND
AGND
100pF

```
ADDR. OPCODE   LABEL     MNEMONIC        COMMENTS
2000  97                 SUB A           ;Zero accumulator
2001  D303               OUT 3           ;Set data direction (8335)
2003  3E02               MVI A,2         ;Set accum to 02
2005  D302               OUT 2           ;Set PA1=OUT line & PA0=IN
2007  3C                 INR A           ;Set accum TO 03
2008  D320               OUT 20h         ;Send 03 to command reg.
200A  97       CONV:     SUB A           ;Zero accum.
200B  D300               OUT 0           ;Make PA1=0 for read signal
200D  3E                 MVI A,2         ;Set accum to 02
200F  D300               OUT 0           ;PA1 SET=1 start conversion
2011  DB00     WAIT:     IN  0           ;Test busy line
2013  0F                 RRC             ;Busy rotated into carry
2014  D21120             JNC WAIT        ;If busy=low wait
2017  DB01               IN 01           ;Busy=high conversion over
2019  D322               OUT 22          ;Send data code to port (22)
201B  C30A20             JMP CONV        ;Another conversion
```

PROGRAM: ELECTRONICS

TASK: ANALOG-TO-DIGITAL CONVERTERS

TASK # F1-13.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ___________

EVALUATOR'S NAME ___________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Prepare the software and hardware to interface analog-to-digital converters to the microprocessor.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 55 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 55 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

ANALOG-TO-DIGITAL CONVERTERS

F1-13.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
*1.	Was 100% of program entered?	Y N
*2.	Did program function with 100% accuracy?	Y N
3.	Was required equipment used?	Y N
*4.	Was required date recorded?	Y N
5.	Was equipment used according to specifications?	Y N
*6.	Were all safety precautions followed?	Y N
7.	Was equipment returned to proper storage area?	Y N

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

STUDENT'S SCORE _____

ANALOG-TO-DIGITAL CONVERTERS

EXAM F1-13.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on analog-to-digital converters. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F1-13.4

1. A device which changes an analog signal to a digital signal is _____________.

   A. DAC
   B. SAR
   C. ADC
   D. None of these

2. An essential part of most analog-to-digital converters is a _____________.

   A. Comparator
   B. Ladder network
   C. D/A
   D. SAR

3. The main advantage of a flash converter is _____________.

   A. Its circuit simplicity
   B. Its speed
   C. Both of these
   D. Neither of these

4. The single-ramp type A/D has the disadvantage of _____ when compared to the dual-ramp A/D.

   A. Circuit simplicity
   B. Speed
   C. Ease of interfacing
   D. Not using a D/A

5. The dual-ramp A/D uses ________ where the single-ramp does not.

   A. A D/A converter
   B. Parallel comparators
   C. An SAR
   D. An integrator

6. One of the main differences between the single counter A/D and the dual-slope A/D is _____________.

   A. A D/A converter
   B. An SAR
   C. A triple phase clock
   D. None of these

7. One of the main advantages of successive-approximation A/D converter is ______________.

   A. Fewer internal components
   B. No D/A converter
   C. Speed and resolution
   D. None of these

8. An 8-bit successive-approximation A/D converter can complete a conversion cycle in ______________.

   A. 256 clk. pulses
   B. 128 clk. pulses
   C. 8 clk. pulses
   D. 64 clk. pulses

9. Quantifying error is another way of specifying ______________.

   A. Slew rate
   B. Resolution
   C. Common mode rejection
   D. Conversion time

10. The dual-slope A/D converter is fastest.

    A. True
    B. False

EXAM KEY F1-13.4

1. C
2. A
3. B
4. B
5. D
6. A
7. C
8. C
9. B
10. B

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (6800)

F2-1: MICROCOMPUTER AND MICROPROCESSOR

TASK: Describe the basic operation of a microprocessor and a microcomputer.

PURPOSE: In microprocessor electronics a technician should know the basic characteristics of microprocessors and microcomputers. This knowledge will enable you to more readily obtain employment. With microprocessors appearing in more and more equipment, it is necessary to understand the operation and requirements of the microprocessor. This learning guide will explain microprocessors and microcomputers and their related terms.

OBJECTIVE: Given a written examination, you will describe the basic operation of a microcomputer and a microprocessor. To master this task you must score at least 80% on the written examination.

ESTIMATED CLASS TIME: 5 HOURS

MICROCOMPUTER AND MICROPROCESSOR

LEARNING STEPS

F2-1

READ:	Information Sheet F2-1.1, "Introduction to Microcomputers." Material on microcomputer terms and conventions.
READ:	Information on microcomputer basics in one or more of the following resources.
COMPLETE:	Activity Sheet F2-1.2, "Introduction to Microcomputers."
READ:	Information Sheet F2-1.3, "Introduction to Microprocessors." Material on microprocessor terms and conventions.
COMPLETE:	Activity Sheet F2-1.4, "Introduction to Microprocessors."
REVIEW:	Information Sheets F2-1.1, F2-1.3, and Activity Sheets F2-1.2, F2-1.4.
COMPLETE:	Laboratory performance on microprocessor trainer operation. Contact your instructor.
COMPLETE:	Performance Checklist F2-1.7.
COMPLETE:	Written Examination F2-1.8, for mastery of this task.

ADVANCED STUDY

READ:	Information Sheet F2-1.5, and material on microcomputer and microprocessor architecture.
COMPLETE:	Activity Sheet F2-1.6, microcomputer and microprocessor architecture.
REVIEW:	Information Sheet F2-1.5, and Activity Sheet F2-1.6.
COMPLETE:	Written Examination F2-1.9, for mastery of this task.
COMPLETE:	Laboratory performance on entering and running programs on the trainer. Contact your instructor.

MICROCOMPUTER AND MICROPROCESSOR

RESOURCES

F2-1

1. Brunner, INTRODUCTION TO MICROPROCESSORS (Reston, 1982).
2. Gilmore, INTRODUCTION TO MICROPROCESSORS.
3. Motorola, MICROPROCESSOR APPLICATION MANUAL.
4. Heathkit, MICROPROCESSORS.
5. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS.
6. Branko and Sopucek, MICROPROCESSORS AND MICROCOMPUTERS.
7. Goody, THE VERSATILE MICROCOMPUTER (SRA, 1982).
8. Additional references as available.

REQUIRED EQUIPMENT

6800 MICROPROCESSOR TRAINER

INFORMATION SHEET

F2-1.1

INTRODUCTION TO MICROCOMPUTERS

A microcomputer is a device that manipulates data. This data may be in the form of numbers or letters. Within the microcomputer is an electronic device known as the Central Processing Unit or CPU. The CPU has the ability to perform arithmetic operations and control the operation of the microcomputer through the use of instructions.

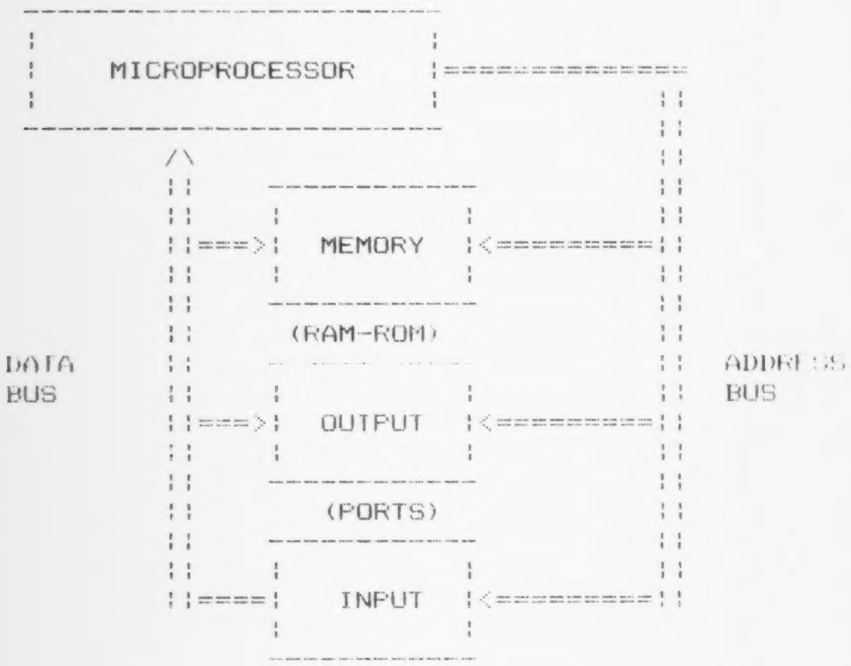
All computers, including microcomputers, are machines that have the following characteristics:

1. An input, the area or device through which data and instructions may be entered.
2. A memory, the area or device in which data and instructions may be stored.
3. An arithmetic logic unit, the area or device in which arithmetic functions and logic are performed.
4. A control section, the area or device in which the instructions are decoded and executed.
5. An output, the area or device from which data or control signals are received.

Microcomputers which contain these features and have the ability to store both their program and data (the stored program concept) are known as **von Neumann** computers. Today it is possible to purchase a single electronic integrated circuit which has all of these features. This is an actual computer-on-a-chip. This form of microcomputer is used in devices such as digital watches, video games, traffic control (stop & go lights), robotics, and many others.

Other microcomputers have separate integrated circuits for each function. The Arithmetic Logic Unit (ALU) and control section are often located within a single chip, called the microprocessor. The microprocessor is the "brain" of the computer, but it really has little or no memory. The memory and input/output devices are separate, integrated circuits connected to the microprocessor through data and address buses. The programmable memory contained within the microcomputer is called Random Access Memory or RAM. The actual connections between the microcomputer and I/O devices are made through locations known as ports.

As powerful as this microcomputer is, it is useless without some form of program. A program is often written in a high level language such as BASIC, FORTRAN, COBOL, C, ADA, or PASCAL among others. The program, when executed, will produce some type of output based upon the data that it contained or was entered through an input port connected to a device such as a keyboard or terminal.



Block diagram of a microcomputer.

The output from a microcomputer is often sent to a printing device. The printer itself may actually contain a dedicated microcomputer that takes the signal from our original microcomputer and changes the electrical impulses into the proper size and times impulses to create the printed characters. The device need not be a simple printer. It may be a high-speed ink-jet printer that is capable of printing in many different colors. Or it may be a plotter, a robot, a graphic display terminal, or any other peripheral device that is designed to receive the data from the output port.

The need to do bigger things faster has led to an increase in the memory size of the microcomputer and the need for higher speed and larger external storage devices such as floppy and hard disks. Programs may be purchased already stored on these disks. Other programs may come permanently written into a Read Only Memory (ROM) cartridge that simply plugs into the microcomputer.

ACTIVITY SHEET

F2-1.2

INTRODUCTION TO MICROCOMPUTERS

Define the following terms as they relate to a microcomputer:

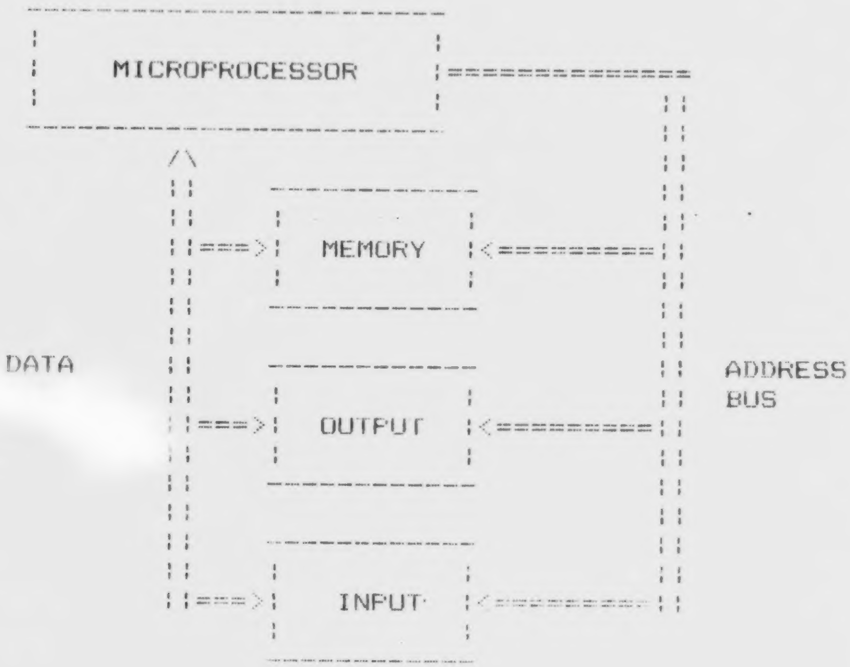
- input
- I/O
- instruction
- stored program concept
- ALU
- memory
- RAM
- bus
- port
- output
- I/O device
- program
- MPU
- address
- write
- peripheral
- ROM
- computer-on-a-chip

INFORMATION SHEET

F2-1.3

INTRODUCTION TO MICROPROCESSORS

A microprocessor is a Very Large Scale Integrated (VLSI) electronic circuit contained within a single chip. A microprocessor is the actual working circuitry of a microcomputer; it contains the ALU and the control section. In addition, it houses accumulators and registers that are used to communicate with the RAM, ROM, and input/output devices.



Block diagram of a microprocessor based microcomputer.

Microprocessors communicate with other devices over data and address buses. The typical size for a microprocessor data bus is 8 bits, 16 bits, or 32 bits. A bit is a Binary Digit, a one or a zero. Each bit corresponds to an electrical connection between the microprocessor and the external device. A group of 8 bits is referred to as a byte. The byte is the correct size to hold the code for numbers and letters that the microprocessor within a microcomputer will need to manipulate.

The address bus size ranges from 8 bits to more than 24 bits, enabling the latter microprocessor to address 2^{24} or over 16 million bytes of memory. Eight-bit microprocessors usually have a 16-bit address bus enabling them to address 2^{16} or 65,536 memory locations, or bytes.

To operate properly the microprocessor needs a clock. The frequency of the clock determines the operating speed of the microprocessor. The actual clock frequency for 8-bit microprocessors is in the 1 MHz to 2 MHz range. The faster the clock, the faster the microprocessor will operate. However, all devices, memory and I/O circuits must be capable of operating at this speed also.

ACTIVITY SHEET

F2-1.4

INTRODUCTION TO MICROPROCESSORS

Define the following terms as they relate to a microprocessor:

- input
- I/O
- instruction
- MPU
- byte
- ALU
- memory
- RAM
- execute
- mnemonic
- bus
- data bus
- address bus
- control bus
- output
- I/O device
- program
- ROM
- operand
- address
- write
- fetch
- MPU cycle
- opcode
- CPU

INFORMATION SHEET

F2-1.5

MICROPROCESSOR ARCHITECTURE

A typical microprocessor has an arrangement of parts that is known as its architecture.

All microcomputers have an instruction decoder which converts the binary code into a sequence of electrical impulses which make the circuit work. The circuit using these electrical signals is the controller which keeps the fetch and execute cycles and the data transfers within the microprocessor unit (MPU) in step.

In addition, there is an accumulator that is used to hold or "accumulate" the results of an arithmetic logic unit (ALU). The accumulator is simply a byte size set of flip-flops forming a register that can hold a binary number.

Other registers used in a microprocessor are the data register, address register, and program counter. The program counter keeps track for the MPU of the next instruction to be executed in the program.

```
PROGRAMMING MODEL OF THE 6800 MPU

8               0 8               0
----------------- -----------------
¦     ACCB      ¦ ¦      ACCA     ¦   Accumulator
----------------- -----------------

16                                0
-----------------------------------
¦               IX                ¦   Index Register
-----------------------------------

16                                0
-----------------------------------
¦               PC                ¦   Program Counter
-----------------------------------

16                                0
-----------------------------------
¦               SP                ¦   Stack Pointer
-----------------------------------

                  7               0
                  -----------------
                  ¦1¦1¦H¦I¦N¦Z¦V¦C¦   Condition Code Register
                  -----------------
                   ^ ^ ^ ^ ^ ^ ^ ^
                   ¦ ¦ ¦ ¦ ¦ ¦ ¦ ¦ ---- Carry Register
     Not Used ------ ¦ ¦ ¦ ¦ ¦ ------ Overflow
     Always 1        ¦ ¦ ¦ ¦ -------- Zero
                     ¦ ¦ ¦ ---------- Negative
                     ¦ ------------ Interrupt
                     -------------- Half Carry (from bit 3)
```

ACTIVITY SHEET

F2-1.6

INTRODUCTION TO MICROPROCESSORS

Explain the purpose of the following circuits in a typical microprocessor:

- accumulator (register)
- instruction decoder
- data register
- condition code register
- program counter
- controller
- address register

PROGRAM: ELECTRONICS

TASK: MICROCOMPUTER AND MICROPROCESSOR

TASK #: F2-1.7

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Describe the basic operation of a microprocessor and a microcomputer.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

MICROCOMPUTER AND MICROPROCESSOR

F2-1.7

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required data recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

MICROCOMPUTER AND MICROPROCESSOR

EXAM F2-1.8

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on microcomputers and microprocessors codes. Each of the statements below is true or false. Place the correct answer (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F2-1.8

1. A microprocessor is a logic device that is used in microcomputers.

   A. True
   B. False

2. Information transmitted to the outside world from the microcomputer goes through an input port.

   A. True
   B. False

3. A bit is a binary digit and may be 0, 1, or 2.

   A. True
   B. False

4. A group of parallel conductors which carry information is called a bus.

   A. True
   B. False

5. A byte is a group of 4 bits.

   A. True
   B. False

6. A printer is considered to be an output peripheral device for a microcomputer.

   A. True
   B. False

7. RAM (Random Access Memory) commonly refers to write only memory.

   A. True
   B. False

8. ROM (Read Only Memory) commonly refers to random access read only memory.

   A. True
   B. False

9. A group of instructions that allows the computer to perform a specific job is called a program.

   A. True
   B. False

10. Microcomputers with floppy diskettes are unable to use ROM cartridges.

    A. True
    B. False

EXAM F2-1.9

Draw the block diagram of a typical microprocessor and explain the logic flow through the data register, instruction decoder, controller sequencer, ALU, program counter, and address register.

EXAM KEY F2-1.8

1. A
2. B
3. B
4. A
5. B
6. A
7. B
8. A
9. A
10. B

EXAM KEY F2-1.9

The response to this test is microprocessor dependent.

```
PROGRAMMING MODEL OF THE 6800 MPU

8               0 8               0
----------------- -----------------
¦     ACCB      ¦ ¦     ACCA      ¦   Accumulator
----------------- -----------------

16                                0
-----------------------------------
¦                IX               ¦   Index Register
-----------------------------------

16                                0
-----------------------------------
¦                PC               ¦   Program Counter
-----------------------------------

16                                0
-----------------------------------
¦                SP               ¦   Stack Pointer
-----------------------------------

                  7             0
                  -----------------
                  ¦1¦1¦H¦I¦N¦Z¦V¦C¦   Condition Code Register
                  -----------------
                   ^ ^ ^ ^ ^ ^ ^ ^
                   ¦ ¦ ¦ ¦ ¦ ¦ ¦ ---- Carry Register
      Not Used ------  ¦ ¦ ¦ ¦ ¦ ---- Overflow
      Always 1         ¦ ¦ ¦ ¦ ------ Zero
                       ¦ ¦ ¦ -------- Negative
                       ¦ ¦ ---------- Interrupt
                       ¦ ------------ Half Carry (from bit 3)
```

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (6800)

F2-2: NUMBERING SYSTEMS AND CODES

TASK: Convert numbers from one radix to another and explain the function of binary codes.

PURPOSE: To understand the operation and applications of microprocessors you must understand decimal, binary, and hexadecimal numbering systems and codes. It is necessary to be able to convert rapidly from one numbering system to another. You must also understand how binary codes represent alphanumeric data. This learning guide will explain the terms and processes necessary to convert a number from one radix to another radix and the basic codes used in equipment today.

OBJECTIVE: Given a written examination, you will convert from one radix to another and explain binary codes. To master this task you must score at least 80% on a written examination and laboratory exercise.

ESTIMATED CLASS TIME: 5 HOURS

NUMBERING SYSTEMS AND CODES

LEARNING STEPS

F2-2

READ: Information Sheet F2-2.1, "Decimal, Binary and Hexadecimal Number Systems."

READ: Information on number systems from one or more of the following resources.

COMPLETE: Activity Sheet F2-2.2, "Decimal, Binary and Hexadecimal Number Systems."

READ: Information Sheet F2-2.3, "Binary Codes." Material on binary codes.

COMPLETE: Activity Sheet 2.4, "Binary Codes."

REVIEW: Information Sheets F2-2.1, F2-2.3, and Activity Sheet F2-2.2, F2-2.4.

COMPLETE: Laboratory performance on number systems and codes. Contact your instructor.

COMPLETE: Performance Checklist F2-2.5.

COMPLETE: Written Examination F2-2.6 for mastery of this task.

NUMBERING SYSTEMS AND CODES

RESOURCES

F2-2

1. Brunner, INTRODUCTION TO MICROPROCESSORS (Reston, 1982).
2. Gilmore, INTRODUCTION TO MICROPROCESSORS.
3. Motorola, MICROPROCESSOR APPLICATION MANUAL.
4. Heathkit, MICROPROCESSORS.
5. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS.
6. Branko and Sopucek, MICROPROCESSORS AND MICROCOMPUTERS.
7. Goody, THE VERSATILE MICROCOMPUTER (SRA, 1982).
8. Additional references as available.

REQUIRED EQUIPMENT

6800 MICROPROCESSOR TRAINER

INFORMATION SHEET

F2-2.1

DECIMAL, BINARY AND HEXADECIMAL NUMBER SYSTEMS

Every technician is familiar with the base 10 number system. This is the counting system, using the numbers 0, 1, 2, 3, 4, 5, 6, 7, 8, and 9. This is a useful system and is used throughout science and industry.

In all microcomputers and digital computers only two conditions are available, on and off, logic 1 and logic 0. A +5 volt input could be defined as a logic 1, and 0 volts as a logic 0. Therefore all inputs to a microprocessor must be a logic 1 or a logic 0.

In most numbering systems, each digit has positional value. The number 327_{10} is the equivalent of 300 + 20 + 7. This may also be expressed as:

327_{10}

:::

::---> $7 \times 10^0 = 7$

::

:----> $2 \times 10^1 = 20$

:

-----> $3 \times 10^2 = 300$

$\overline{327}_{10}$

To convert a decimal or base 10 number to a binary or base 2 number, keep dividing the decimal number by 2 until the number is 0, and list the remainders. For example, the number 25_{10} is converted to the base 2 as follows:

Step 1 - divide the base 10 number by 2:

$\begin{array}{r}12\\2\overline{)25}\end{array}$ Remainder = 1

Step 2 - divide step 1 answer of 12 by 2:

$\begin{array}{r}6\\2\overline{)12}\end{array}$ Remainder = 0

INFORMATION SHEET F2-2.1 CONT'D.

Step 3 - divide step 2 answer of 6 by 2:

$\begin{array}{r} 3 \\ 2\overline{)6} \end{array}$ Remainder = 0

Step 4 - divide step 3 answer of 3 by 2:

$\begin{array}{r} 1 \\ 2\overline{)3} \end{array}$ Remainder = 1

Step 5 - divide step 4 answer of 1 by 2:

$\begin{array}{r} 0 \\ 2\overline{)1} \end{array}$ Remainder = 1

Step 6 - stop dividing when the answer becomes zero.

Step 7 - read the remainders from bottom to top (reverse order) to form the answer.

$25_{10} = 1\ \ 1\ \ 0\ \ 0\ \ 1_2$

```
         ^  ^  ^  ^  ^
         |  |  |  |   ----Remainder from step 1.
         |  |  |   ------Remainder from step 2.
         |  |   ---------Remainder from step 3.
         |   ------------Remainder from step 4.
          ---------------Remainder from step 5.
```

To verify the answer use positional notation on the base 2 number 11001 and convert it back to a base 10 number.

$1\ \ 1\ \ 0\ \ 0\ \ 1_2$

```
|  |  |  |  |
|  |  |  |   --->1 x 2^0 =  1
|  |  |   ------>0 x 2^1 =  0
|  |   --------->0 x 2^2 =  0
|   ------------>1 x 2^3 =  8
 --------------->1 x 2^4 = 16
                          ----
```

25_{10} (The original number.)

The small subscript number indicates the radix or base of the numbering system.

Another form of binary number is the binary coded decimal or BCD number. This number is **always** a 4-digit binary number corresponding to a decimal number equivalent. The table below illustrates the relationship between BCD, binary, and decimal numbers.

decimal	binary	BCD
1	1	0001
2	10	0010
3	11	0011
4	100	0100
5	101	0101
6	110	0110
7	111	0111
8	1000	1000
9	1001	1001
10	1010	0001 0000
11	1011	0001 0001
12	1100	0001 0010
13	1101	0001 0011
14	1110	0001 0100
15	1111	0001 0101
16	10000	0001 0110

Additional numbering systems encountered in microprocessors are the octal, having a base of 8, and hexadecimal, having a base of 16. The octal numbers are not widely used in the computer industry today. The hexadecimal numbers are now more common. In the previous table, the BCD number is a constant 4-digit size. but, four binary digits allow counting from 0 to 15_{10}. If BCD is used to represent only decimal numbers, there would be an efficiency of only 10/16, or 62.5%. Most of the spaces would not be used. To make 100% efficient use of BCD numbers, there was developed the hexadecimal (base 16) number system. This system is equivalent to the decimal system from 0 through 9. However, from 10 to 15, the letters A through F are used.

INFORMATION SHEET F2-2.1 CONT'D.

The following is a comparison of the three most often used number systems in addition to binary.

Base 10 (decimal)	Base 16 (hexadecimal)	BCD (binary coded decimal)
0	0	0000
1	1	0001
2	2	0010
3	3	0011
4	4	0100
5	5	0101
6	6	0110
7	7	0111
8	8	1000
9	9	1001
10	A	1010
11	B	1011
12	C	1100
13	D	1101
14	E	1110
15	F	1111
:	:	:
255	FF	1111 1111
:	:	:
4095	FFF	1111 1111 1111
:	:	:
65535	FFFF	1111 1111 1111 1111

ACTIVITY SHEET

F2-2.2

NUMBERING SYSTEMS AND CODES

1. Convert any decimal number into its binary, hexadecimal, and BCD equivalent and back.

2. Define the following terms:

   radix
   integer
   binary
   hexadecimal
   bit
   decimal
   octal
   BCD

INFORMATION SHEET

F2-2.3

BINARY CODES

In addition to numbers, microprocessors must often handle letters and punctuation. To enable the microprocessor to accomplish, each character is assigned a binary number or code. The most common code is the ASCII code. This is the American Standard Code for Informational Interchange. The ASCII code is a 7-bit code used to allow communication between the microprocessor and an interconnected device. The establishment of the standard code allows different brands of equipment to communicate properly. With seven bits the code is able not only to represent numbers, letters, and punctuation, but also non-printable codes such as those required for backspace, bell, and carriage return. The following is a list of ASCII conversions.

ASCII CODE

	COLUMN	0 (3)	1 (3)	2 (3)	3	4	5	6	7 (3)
ROW	BITS 4321 ⇩ 765 ⇨	000	001	010	011	100	101	110	111
0	0000	NUL	DLE	SP	0	@	P	`	p
1	0001	SOH	DC1	!	1	A	Q	a	q
2	0010	STX	DC2	"	2	B	R	b	r
3	0011	ETX	DC3	#	3	C	S	c	s
4	0100	EOT	DC4	$	4	D	T	d	t
5	0101	ENQ	NAK	%	5	E	U	e	u
6	0110	ACK	SYN	&	6	F	V	f	v
7	0111	BEL	ETB	'	7	G	W	g	w
8	1000	BS	CAN	(	8	H	X	h	x
9	1001	HT	EM	)	9	I	Y	i	y
10	1010	LF	SUB	*	:	J	Z	j	z
11	1011	VT	ESC	+	;	K	[	k	{
12	1100	FF	FS	,	<	L	\	l	¦
13	1101	CR	GS	–	=	M	]	m	}
14	1110	SO	RS	.	>	N	⌒ (1)	n	~
15	1111	SI	US	/	?	O	— (2)	o	DEL

An old code still in use in some equipment is the BAUDOT code. This is a five character code similar to ASCII. With just 5-bits, only 32 discrete characters can be represented. Because of this limited character set, the ASCII code was developed.

A problem that occurs when interfacing microprocessors to equipment in the real world is that the microprocessors are so fast that they can respond to intermittent conditions. When you are inputing a 4-bit binary number using switches, the step between each number should be a single bit change, but it isn't. The change from 0000_2 to 0001_2 is a single bit/switch change. On the next change, there will be a single count increase, but two bits must change as 0001_2 becomes 0010_2. Now, if you were switching the input switches, should you change 0001 to 0011 and then to 0010 or should you change 0001 to 0000 and then to 0010? Even if you activated both switches at the same time, the microprocessor will detect differences between the switches smaller than 1/1000000 of a second.

To overcome this a new binary counting code was developed called the Gray code. The following is a comparison of standard binary code to gray code.

DECIMAL	BINARY	GRAY
0	0000	0000
1	0001	0001
2	0010	0011
3	0011	0010
4	0100	0110
5	0101	0111
6	0110	0101
7	0111	0100
8	1000	1100
9	1001	1101

Notice that the number of bits that change between each digit in the gray code is always only one. In the standard binary count, the change between 7 and 8 involves all four bits, and can produce momentarily any value between 0000_2 and 1111_2 before arriving at the value of 1000_2.

ACTIVITY SHEET

F2-2.4

BINARY CODES

1. Define the following terms:

   parity
   LSD
   MSB
   LSB
   MSD
   Gray code
   ASCII
   BAUDOT

2. Convert a letter or number into an ASCII binary code, and convert an ASCII binary code into its letter or number equivalent.

PROGRAM: ELECTRONICS

TASK: NUMBERING SYSTEMS AND CODES

TASK #: F2-2.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Convert numbers from one radix to another and explain the function of binary codes.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

NUMBERING SYSTEMS AND CODES

F2-2.5

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required data recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

NUMBERING SYSTEMS AND CODES

EXAM F2-2.6

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on numbering systems and codes. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F2-2.6

1. The decimal number 564 is equal to __________.

   A. fifteen
   B. 5 hundreds + 6 tens + 4 ones
   C. 5 + 6 + 4
   D. 256 to the base 2

2. In the binary number system, the two digits that are used are __________.

   A. 0 and 1
   B. 1 and 2
   C. 0 and 2
   D. 1 and -1

3. In the binary number system, the base of the number is two. Therefore, base two to the third power is equal to __________.

   A. 3
   B. 6
   C. 8
   D. 16

4. The binary number 10101 is equal to the base 10 number __________.

   A. 10,101
   B. 3
   C. 18
   D. 21

5. The binary number 10001 is equal to the decimal number __________.

   A. 2
   B. 15
   C. 16
   D. 17

6. The base 10 number 23 is equal to the base 2 number __________.

   A. 11101
   B. 10111
   C. 11011
   D. 11110

7. Decimal 31 converted to binary is equal to ___________.

   A. 10000
   B. 11110
   C. 11111
   D. 100001

8. The 7 bit ASCII code for decimal 1 is ___________.

   A. 0011110
   B. 0110001
   C. 0000001
   D. 1000000

9. Which of the following is a proper result in the Gray code number 0111 when 1 is added?

   A. 10101
   B. 1001
   C. 0101
   D. 1011

10. What is the BCD equivalent of the binary number 11101101?

   A. 1110 1101
   B. 0001 0010
   C. 0010 0011 0111
   D. 1101 1100 1000

EXAM KEY F2-2.6

1. B
2. A
3. C
4. D
5. D
6. B
7. C
8. B
9. C
10. C

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (6800)

F2-3: MACHINE LANGUAGE PROGRAMMING

TASK: Write, enter, verify and run simple machine language programs.

PURPOSE: The writing, entering, verifying and running of a machine language program is fundamental to the understanding of the operation, application and repair of microprocessors. This learning guide will provide the opportunity to write, enter, verify and run a machine language program.

OBJECTIVE: Given a written examination, you will identify the correct information necessary to write, enter, verify and run a machine language program. To master this task you must score at least 80% on the written examinations and laboratory exercises.

ESTIMATED CLASS TIME: 5 HOURS

MACHINE LANGUAGE PROGRAMMING

LEARNING STEPS

F2-3

READ: Information Sheet F2-3.1, "Machine Language Programming."

READ: Information on 6800 machine language from one or more of the following references.

COMPLETE: Activity Sheet F2-3.2, "Machine Language Programming."

REVIEW: Information Sheet F2-3.1, and Activity Sheet F2-3.2.

COMPLETE: Laboratory performance on machine language programming." Contact your instructor.

COMPLETE: Performance Checklist F2-3.3.

COMPLETE: Written Examination F2-3.4 for mastery of this task.

MACHINE LANGUAGE PROGRAMMING

RESOURCES

F2-3

1. Brunner, INTRODUCTION TO MICROPROCESSORS (Reston, 1982).
2. Gilmore, INTRODUCTION TO MICROPROCESSORS.
3. Motorola, MICROPROCESSOR APPLICATION MANUAL.
4. Heathkit, MICROPROCESSORS.
5. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS.
6. Branko and Sopucek, MICROPROCESSORS AND MICROCOMPUTERS.
7. Goody, THE VERSATILE MICROCOMPUTER (SRA, 1982).
8. Additional references as available.

REQUIRED EQUIPMENT

6800 MICROPROCESSOR TRAINER

INFORMATION SHEET

F2-3.1

MACHINE LANGUAGE PROGRAMMING

All microprocessors can perform the basic functions of arithmetic, control and instruction decoding. The corresponding logic blocks are called the arithmetic logic unit (ALU), control sequencer, and instruction decoder. Also, the MPU contains basic fundamental registers. These registers are the accumulator, data register, address register, and program counter.

The ALU handles all of the arithmetic and logic comparisons. The arithmetic operation that is performed most often is simple addition. Since the addition of negative numbers is the equivalent of subtraction, the ALU subtracts by first complementing a number and adding it to a second number to produce a difference. The complement generated by most microprocessors is the 2's complement. Performing 2's complement addition is equivalent to subtraction. All arithmetic operations can be accomplished by repeated operations of addition and subtraction. Many of the new 16-bit and 32-bit microprocessors have hardware multiplication and division instructions. These instructions are much faster than writing the routines in software.

ALU's can also perform basic logic operations. These operations usually include logical multiplication (AND), logical addition (OR), inversion (NOT), and exclusive or (XOR). In addition to these operations the MPU is capable of assorted shifting and rotating instructions. One commonly used logic operation is the AND function used to mask or clear bit-flags.

The instruction decoder interprets each instruction for proper operation by the ALU. Every instruction is brought into the MPU for decoding. Each binary number instructs the microprocessor to carry out a sequence of operations that will produce the required result.

The controller sequencer keeps all of the assorted tasks within the MPU in step. Each instruction requires different combinations of control signals to accomplish the desired function. The controller sequencer produces the proper control signals in the proper order to keep the microprocessor functioning.

The data register receives all the data and instructions that the MPU will use. The program counter holds the address of the next instruction to be decoded and controls the sequence in which the instructions in a program are performed. The accumulator, a register in the MPU through which all operands must pass, holds the results of arithmetic and logic

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functions. There may be more than one accumulator (register).

The flow of an instruction through the MPU is:

-instruction enters the data register.
-data register transfers the instruction to the instruction decoder.
-instruction is decoded and executed. Depending upon the instruction, either data is extracted from the memory, or another instruction will be fetched.
-during this time the program counter will be updated.
-address register will be modified as necessary.
-accumulator will be changed as necessary.

Some of the simplest instructions for the MPU have inherent, immediate, or direct addressing modes. An addressing mode is an inherent part of each instruction. The addressing is necessary to tell the microprocessor where the data is that is to be operated upon.

An instruction has inherent addressing when the destination is implied in the instruction. Load Accumulator is an implied address instruction. It is not necessary to tell the MPU where the accumulator is located. In some microprocessors there are two or more accumulators, and it is necessary to distinguish between the different accumulators, but each instruction is still considered to have inherent addressing.

Immediate addressing tells the MPU to act upon the contents of the next (immediate) memory location. Load Immediate is an example of an immediate address instruction. The advantage of the immediate addressing mode is that it does not need to be decoded. This allows the microprocessor to operate at maximum speed. The disadvantage of immediate addressing is that the data must be included as part of the program. This is a problem if the data is in a read only memory. It is not possible to change the data in ROM. Thus, as a program executes it is not possible to manipulate any of the data.

Direct addressing tells the MPU to act upon the contents of memory that is specified by only an 8-bit address. In the 6800, this restricts this type of instructions to the first page of memory, or the first 256 bytes from 0 - FF_{16} in the memory. This area in memory is often reserved for variable storage. The reason for storing variables in this page of memory is that they can be operated upon by direct addressing instructions which have very short execution times.

The actual operation of any instruction and additional information can be found in the detailed description of the instruction set. All manufacturers of microprocessors provide this information in both booklet form and as programming instruction cards.

ACTIVITY SHEET

F2-3.2

MACHINE LANGUAGE PROGRAMMING

1. Trace the data flow that takes place between the various circuits during the execution of a simple program using a simplified block diagram of a hypothetical microprocessor.

2. Describe the difference between inherent, immediate, and direct addressing.

3. Write a simple straight-line program that can be executed by the microprocessor trainer.

4. Enter the program into the microprocessor trainer and execute it.

PROGRAM: ELECTRONICS

TASK: MACHINE LANGUAGE PROGRAMMING

TASK #: F2-3.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ___________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Write, enter, verify and run simple machine language programs.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

MACHINE LANGUAGE PROGRAMMING

F2-3.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required data recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

MACHINE LANGUAGE PROGRAMMING

EXAM F2-3.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on machine language programming. Each of the statements is true or false. Place the letter associated with that choice (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F2-3.4

1. Addressing mode refers to the method by which an instruction addresses its operand.

    A. True
    B. False

2. The increment accumulator instruction is a single-byte instruction.

    A. True
    B. False

3. Two-byte instructions use the implied addressing mode.

    A. True
    B. False

4. Inherent addressing modes require less memory space than direct addressing modes.

    A. True
    B. False

5. In inherent addressing modes, the fetch phase requires two (2) MPU cycles.

    A. True
    B. False

6. The time required for an instruction to be fetched and executed is equal to the reciprocal of the clock frequency.

    A. True
    B. False

7. Direct addressing modes require more memory space than inherent addressing modes.

    A. True
    B. False

8. The store immediate instruction uses less memory than the store direct the arithmetic logic unit (ALU), the controller sequencer, the instruction decoder, the arithmetic logic unit (ALU), the controller sequencer, the instruction decoder, addressing mode.

   A. True
   B. False

9. All direct addressing mode instructions require one or more additional MPU cycles to execute.

   A. True
   B. False

10. Immediate addressing of an operand is most useful when the operand is a variable.

    A. True
    B. False

EXAM KEY F2-3.4

1. A
2. A
3. B
4. A
5. B
6. B
7. A
8. B
9. A
10. B

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (6800)

F2-4: MICROPROCESSOR ARITHMETIC

TASK:	Write, enter, verify and run a machine language arithmetic.
PURPOSE:	One of the principal tasks performed by the microprocessor is arithmetic functions. To understand arithmetic programs used in microprocessors you must analyze machine language arithmetic programs. This learning guide will explain the terms and processes necessary to write, enter, verify and run machine language arithmetic programs.
OBJECTIVE:	Given a written examination, you will identify the correct information necessary to write, enter, verify and run an arithmetic machine language program. To master this task you must score at least 80% on the written examinations and laboratory exercises.

ESTIMATED CLASS TIME: 5 HOURS

MICROPROCESSOR ARITHMETIC

LEARNING STEPS

F2-4

READ: Information Sheet F2-4.1, "6800 Microprocessor Arithmetic." Material on computer arithmetic.

READ: Information on 6800 microprocessor arithmetic from one or more of the following resources.

COMPLETE: Activity Sheet F2-4.2, "6800 Microcomputer Arithmetic."

READ: Information Sheet F2-4.3, "6800 Logic Operations." Material on logic operations.

COMPLETE: Activity sheet 4.4, "6800 Logic Operations."

REVIEW: Information Sheets F2-4.1, F2-4.3, and Activity Sheets F2-4.2, F2-4.4.

COMPLETE: Laboratory performance on 6800 microprocessor arithmetic. Contact your instructor.

COMPLETE: Performance Checklist F2-4.5.

COMPLETE: Written examination F2-4.6 for mastery of this task.

MICROPROCESSOR ARITHMETIC

RESOURCES

F2-4

1. Brunner, INTRODUCTION TO MICROPROCESSORS (Reston, 1982).
2. Gilmore, INTRODUCTION TO MICROPROCESSORS.
3. Motorola, MICROPROCESSOR APPLICATION MANUAL.
4. Heathkit, MICROPROCESSORS.
5. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS.
6. Branko and Sopucek, MICROPROCESSORS AND MICROCOMPUTERS.
7. Goody, THE VERSATILE MICROCOMPUTER (SRA, 1982).
8. Additional references as available.

REQUIRED EQUIPMENT

6800 MICROPROCESSOR TRAINER

INFORMATION SHEET

F2-4.1

6800 MICROPROCESSOR ARITHMETIC

Any number system can be used to perform the two basic operations of addition and subtraction. By using addition and subtraction you can then perform multiplication, division and any other mathematical operation.

Binary addition is performed just like decimal addition. To illustrate binary addition let's add the two numbers 1010 and 1011.

Carry -	1010
Addend -	1010
Augend -	1011
	10101

Binary subtraction is performed in a similar manner. The following is an example of the subtraction of the two numbers 11011 and 1101.

Minuend after borrow -	0	10	10	1	1
Minuend -	1	1	0	1	1
Subtrahend -	-	1	1	0	1
		1	1	1	0

Negative numbers can be represented by using the most significant bit, B7, as the sign bit. When this digit is a 1, the number is negative.

$+\ 8_{10} = 0\underline{0001000}_2$

$+\ 45_{10} = 0\underline{0101101}_2$

$+\ 127_{10} = 0\underline{1111111}_2$

Another method of representing negative numbers in the early days of computers was the one's complement. The one's complement of a number is formed by changing all 0's to 1's and all 1's to 0's. This yields a range of -127_{10} to $+127_{10}$ for an 8-bit number.

$-\ 8_{10} = 1\underline{1110111}_2$

$-\ 45_{10} = 0\underline{1010010}_2$

$-\ 127_{10} = 1\underline{0000000}_2$

INFORMATION SHEET F2-4.1 CONT'D.

The problem with one's complement is that we end up with a positive and a negative zero.

The current method to represent negative numbers is to use a two's complement. A two's complement number is formed by taking a one's complement number and adding one to it. This yields a range of -128_{10} to $+127_{10}$ and only one zero value.

We have already covered the column or place value of whole numbers in both the binary and decimal systems. It is necessary to discuss the positional value of the digits to the right of the decimal point. The table below shows decimal and binary fractional numbers.

DECIMAL	BINARY
10^3 - 1000	2^3 - 8
10^2 - 100	2^2 - 4
10^1 - 10	2^1 - 2
10^0 - 1	2^0 - 1
10^{-1} - 1/10	2^{-1} - 1/2
10^{-2} - 1/100	2^{-2} - 1/4
10^{-3} - 1/1000	2^{-3} - 1/8
. . . .	. . . .

The addition and subtraction of binary fractions follow the same procedures used for whole numbers. Other arithmetic processes including multiplication and division are normally accomplished by programming. There are many different algorithms available to accomplish these different processes.

As stated earlier, it is possible to accomplish multiplication and division by simply using repeated addition and subtraction respectively. The following is an example of the multiplication of 5 and 3 using repeated addition.

START	STEP 1	5	5
	STEP 2	ADD 5	5+5=10
	STEP 3	ADD 5	10+5=10

END

This process can be repeated for any size number with exact accuracy.

To divide two numbers such as 12 by 4, the technique is to keep subtracting the smaller number from the larger number until the result is zero. The number of times that the subtraction takes place is the answer. Remember that the microprocessor cannot subtract, but it can change the sign of the number and add. The following is an example of dividing by repeated addition of a negative number.

START	STEP 1	12	+(-4)	REMAINDER 8
	STEP 2	8	+(-4)	REMAINDER 4
	STEP 3	4	+(-4)	REMAINDER 0
END				

The number of steps required was three. 12 divided by 4 is 3. The process does not always result in a remainder of zero. When it doesn't, a decision must be made to stop and just use the integer result if that is accurate enough. If not, then the program must continue and produce a fractional answer until the remainder is zero, or the desired accuracy is obtained.

When these calculations are performed on large numbers, the process will take a long time as microprocessors measure it. To speed up the calculations there are available mathematical integrated circuits or mathematical co-processors that can perform various mathematical operations hundreds of times faster than the microprocessor. These integrated circuits are used in the larger microcomputers and computers where the calculation of large numbers and/or high speed is required.

ACTIVITY SHEET

F2-4.2

6800 MICROPROCESSOR ARITHMETIC

1. Write programs to add, subtract, multiply, and divide two 8-bit binary numbers.

2. Derive the one's complement of a binary number.

3. Derive the two's complement of a binary number.

4. Write a program for the microprocessor trainer to take the two's complement of any 7-bit binary number and execute the program.

5. List the mathematical instructions for the 6800 microprocessor.

INFORMATION SHEET

F2-4.3

6800 LOGIC OPERATIONS

In addition to performing mathematical processes, the 6800 microprocessor can manipulate binary numbers logically, using the theorems developed by the mathematician George Boole, for Boolean Algebra. The basic functions of boolean algebra are AND, OR, Exclusive OR, and Invert.

The AND function produces the logical product of two or more logic variables. The output is a 1 when all of the inputs are 1's. The output will be a zero if one or more of the inputs is 0. The Boolean formula for a logic AND is:

$$AB = C$$

where A and B are inputs and C is the output. The following is a truth table for the above equation.

INPUTS		OUTPUT
A	B	C
0	0	0
0	1	0
1	0	0
1	1	1

The OR function produces the logical sum of two or more logic variables. The output is a 1 when any of the inputs are 1's. The output will be a zero only when all of the inputs are 0's. The Boolean formula for a logical OR is:

$$A + B = C$$

where A and B are inputs and C is the output.

The Exclusive OR (XOR) function performs a logical test for equality between two logic variables. The output is a 1 when the inputs are not the same. The output will be a zero when the inputs are identical. The Boolean formula for a logical XOR is:

$$A \oplus B = C$$

where A and B are inputs and C is the output.

The Invert function performs a direct complement of a single input variable. The output is a 1 when the input is 0. The output will be 0 when the input is 1. The Boolean formula for an inverter is:

$$A = \overline{A}$$

ACTIVITY SHEET

F2-4.4

6800 LOGIC OPERATIONS

1. Manipulate binary numbers using logical AND, OR , and XOR operations.

2. Logically invert binary numbers.

3. Write a program for the microprocessor trainer to invert any 8-bit binary number and execute the program.

4. List the logical instructions for a 6800 microprocessor.

PROGRAM: ELECTRONICS

TASK: MICROPROCESSOR ARITHMETIC

TASK #: F2-4.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ____________

TERMINAL PERFORMANCE OBJECTIVE:

Write, enter, verify and run a machine language arithmetic.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

MICROPROCESSOR ARITHMETIC

F2-4.5

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required data recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

MICROPROCESSOR ARITHMETIC

EXAM F2-4.6

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on microprocessor arithmetic. Each of the statements is true or false. Place the letter associated with choice (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F2-4.6

1. A microprocessor is a logic element that can perform a variety of tasks.

   A. True
   B. False

2. The circuit in the microprocessor that performs arithmetic and logic operations is called the ALU.

   A. True
   B. False

3. The numbers that are operated upon by the computer are called operands.

   A. True
   B. False

4. An instruction is retrieved from memory and decoded during the fetch phase.

   A. True
   B. False

5. Of the three addressing modes covered, the inherent addressing mode requires the longest execution time.

   A. True
   B. False

6. The ALU in a 6800 is a one's-complement, 8-bit parallel device.

   A. True
   B. False

7. The two's complement of 0111 10101 is 1000 0101.

   A. True
   B. False

8. 111 111 is the largest 8-bit positive number that can be represented by in two's complement form.

   A. True
   B. False

9. When 1010 0011 is XORed with 1100 1100 the result is 0110 1111.

   A. True
   B. False

10. When an inversion (NOT) is performed on a binary number the number becomes negative.

    A. True
    B. False

1612

EXAM KEY F2-4.6

1. A
2. A
3. A
4. A
5. B
6. B
7. B
8. B
9. A
10. A

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (6800)

F2-5: 6800 PROGRAMMING--BRANCHING INSTRUCTIONS

TASK:	Write, enter, verify and run machine language branching programs.
PURPOSE:	The software power of the microprocessor depends upon the power of its instruction set and how it is used. All instruction sets include the powerful branching instructions. These instructions give the microprocessor the ability to make decisions based upon inputs and/or the results of an arithmetic operation. This learning guide will explain the terms and processes necessary to write, enter, verify and run machine language branching programs.
OBJECTIVE:	Given a written examination, you will be able to identify the correct information necessary to write, enter, verify and run machine language branching programs. To master this task you must score at least 80% on the written examinations and laboratory exercises.

ESTIMATED CLASS TIME: 5 HOURS.

6800 PROGRAMMING--BRANCHING INSTRUCTIONS

LEARNING STEPS

F2-5

READ:	Information Sheet F2-5.1, "Programming and Flow Charts." Material on programming.
READ:	Information on programming from the following resource list.
COMPLETE:	Activity Sheet F2-5.2, "Programming and Flow Charts."
READ:	Information Sheet F2-5.3, "6800 Machine Language Programming--Branching Instructions." Material on microprocessor programming.
COMPLETE:	Activity Sheet F2-5.4, "6800 Machine Language Programming--Branching Instructions."
REVIEW:	Information Sheets F2-5.1, F2-5.3, and Activity Sheets F2-5.2, F2-5.4.
COMPLETE:	Laboratory performance on branching programs. Contact your instructor.
COMPLETE:	Performance Checklist F2-5.5.
COMPLETE:	Written Exam F2-5.6 for mastery of this task.

6800 PROGRAMMING--BRANCHING INSTRUCTIONS

RESOURCES

F2-5

1. Brunner, INTRODUCTION TO MICROPROCESSORS (Reston, 1982).
2. Gilmore, INTRODUCTION TO MICROPROCESSORS.
3. Motorola, MICROPROCESSOR APPLICATION MANUAL.
4. Heathkit, MICROPROCESSORS.
5. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS.
6. Branko and Sopucek, MICROPROCESSORS AND MICROCOMPUTERS.
7. Goody, THE VERSATILE MICROCOMPUTER (SRA, 1982).
8. Additional references as available.

REQUIRED EQUIPMENT

6800 MICROPROCESSOR TRAINER

INFORMATION SHEET

F2-5.1

PROGRAMMING AND FLOW CHARTS

Microcomputer programming may be accomplished in many ways. The easiest way is to use a high-level programming language such as Fortran, Cobol, Basic, Pascal, or Ada. Each of these languages enables you to communicate indirectly with the microprocessor within the microcomputer. Compilers are available for each of these languages. A compiler is a computer program that converts (compiles) a high-level language into a form (machine language) that the microcomputer can understand. If the program contains spelling or other syntax errors, the program cannot run. The Basic language is an attempt to solve this problem for beginning programmers. Basic is an example of an interpreted language. An interpreter reads in each line separately, converts it into machine language and executes it. Interpreted languages are easier to write and "debug"; however, they execute much slower than compiled languages.

Fortran is an abbreviation for FORmula TRANslation. This language was developed early in the history of computers, and has been revised often. It is a powerful language for numerical calculations, but it does not manipulate text easily. Fortran is a cryptic or code-oriented language.

Cobol is an acronym for Common Business Oriented Language. As the name implies, Cobol was designed for solving and manipulating business affairs. Also, the language uses common english to communicate to the microprocessor; this makes Cobol easy to learn and makes the programs self-documenting. However, this same feature makes the language unsuitable for non-business oriented tasks.

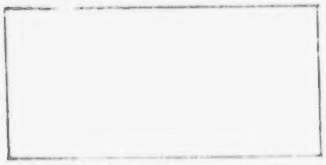
Basic is an acronym for Beginners All-purpose Symbolic Instruction Code. Basic was developed to teach people the fundamentals of programming; however, it has evolved into an all purpose language. This language is capable of performing the functions of all the other languages, but it becomes difficult to maintain the programs as they grow in size. Basic was the first high-level language to be developed for microprocessor based microcomputers.

INFORMATION SHEET F2-5.1 CONT'D.

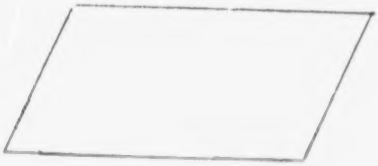
Pascal is another computer language used to teach programming. It is designed for structured programming. Pascal, named after Blaise Pascal, is widely used.

Ada is a programming language used by the United States military. This language is designed to do everything from maintaining the books (instead of using Cobol), to controlling the microprocessors that maintain the flight path of the space shuttle (instead of using assembler).

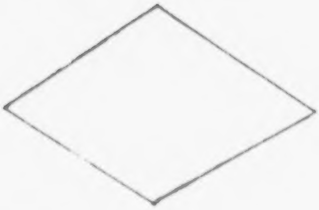
As computers increased in size, so did the programs that were written for them. Soon programs became so large that it was difficult to develop them. A shorthand form of an outline or **flowchart** was developed to aid the writing of programs. The flowchart contains special symbols and is used to assist the programmer in writing the program. Flowcharts are also useful when it is necessary to modify an existing program. The following are typical symbols used in the construction of flowcharts.



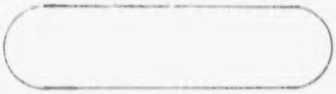
Process



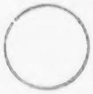
Input or Output



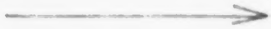
Decision



Continue or End of
Present Function



Connections Between
Pages



Flow Lines

Besides high-level languages, there exists medium- and low-level languages. Machine language is the very lowest level of any language. This is the language used by the microprocessor. Most microprocessor trainers have keyboards that allow you to enter machine language directly into the memory of the microcomputer for execution. This language is in binary form, but is often entered as hexadecimal or sometimes octal numbers.

The advantage of machine language programming is that it is very compact in size when written properly, and it executes very fast. Because it is so difficult to write machine language programs, another program written in machine language was developed called an assembler. An assembler assists in the writing of machine language programs.

ACTIVITY SHEET

F2-5.2

PROGRAMMING AND FLOW CHARTS

1. Explain the difference between machine language, assembly language, interpreted language, and compiled language.
2. Define: assembler, compiler, interpreter, object program, source program, BASIC, FORTRAN, COBOL, PASCAL and ADA.
3. Explain the use of a flowchart.

INFORMATION SHEET

F2-5.3

6800 MACHINE LANGUAGE PROGRAMMING--BRANCHING INSTRUCTION

Writing machine language programs is a difficult task. This task is made easier by adding additional instructions to the instruction set of the microprocessor. These instructions are the branching instructions. These instructions allow you to program repetitive and conditional operations into the microprocessor. They also increase the possibility of writing a program that is difficult to debug and/or modify.

The simplest branching instruction is the unconditional branch. When the microprocessor executes this instruction, it does not test any parameters. When the processor loads and executes this instruction, it always branches to the specified address.

The conditional branches, such as branch if negative, or branch if greater than zero, will not always execute the same way. This type of branch instruction will check the condition of a flag in the condition code register. This additional 8-bit register is available to the microprocessor and contains six bits or flags that monitor the status of the microprocessor. If the correct flag is cleared, set to 0, then the branch will not be executed. If the flag is set, contains a 1, then the branch will be executed, and the flow of the program changed.

One of the features of branch instructions is the ability to branch forward or backward in the memory space. The branch instructions in the 6800 MPU can branch forward 127_{10} and backward 128_{10} memory locations from the address contained in the program counter. Because the branch instructions add to or subtract from the program counter to determine the destination of the branch, the branch is called a relative branch. This means that regardless of where this program is located in memory the branch will always arrive at the correct destination. This capability allows the program to be written in position independent code. A program written in PIC will load into memory at any location and execute properly. The disadvantage of branch instructions is that they can address only one page of memory, 256_{10} bytes out of a possible $65,536_{10}$ locations.

With the many types of branching instructions and their addressing modes, it is important to master the operation of these instructions. The best way to understand the operation of any instruction is to first follow its flow through a block diagram of a microprocessor and try to understand what is happening within the MPU. The last step is to write **simple** programs using each instruction until you can get the program to execute as you designed.

The relative-addressing mode specifies an address based on the contents of the program counter and the offset. The offset is located immediately after the branch opcode. It is the second branch of the instruction. The offset value is the destination address minus the value of the program counter. Remember that the limits of a branch in the 6800 are $+127_{10}$ to -128_{10} and that there is a wide variety of branch instructions available that test the status of the condition code register.

ACTIVITY SHEET

F2-5.4

6800 MACHINE LANGUAGE PROGRAMMING--BRANCHING INSTRUCTION

1. Explain the purpose of conditional and unconditional branching.

2. Trace the data flow during the execution of a branch instruction using the block diagram of a hypothetical microprocessor.

3. Explain the purpose of the carry, negative, zero, and overflow flags in a microprocessor.

PROGRAM: ELECTRONICS

TASK: 6800 PROGRAMMING--BRANCHING INSTRUCTIONS

TASK #: F2-5.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Write, enter, verify and run machine language branching programs.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

6800 PROGRAMMING--BRANCHING INSTRUCTIONS

F2-5.5

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required data recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

6800 PROGRAMMING--BRANCHING INSTRUCTIONS

EXAM F2-5.6

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on 6800 programming--branching instructions. Each of the statements is true or false. Place the letter associated with the correct choice (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F2-5.6

1. Jump and/or branch instructions allow a microprocessor to escape the normal instruction sequence.

   A. True
   B. False

2. The relative-addressing mode instruction indicates the location of data to be fetched.

   A. True
   B. False

3. A relative branch can be used to address any memory location in the memory map of the 6800 from any other memory location.

   A. True
   B. False

4. Jump instructions may be done in the forward direction only in the 6800 MPU.

   A. True
   B. False

5. All branches are conditional branches.

   A. True
   B. False

6. Condition codes or flags are used in conditional branches.

   A. True
   B. False

7. The overflow (V) flag is set when an overflow occurs but is cleared if no overflow occurs.

   A. True
   B. False

8. The BMI instruction tests the negative (N) flag to see if it is set.

   A. True
   B. False

9. The zero (Z) flag is **always** set if the previous instruction left all zeros in the accumulator of the MPU.

   A. True
   B. False

10. The BEQ instruction causes a branch to occur only if the Z flag is cleared.

   A. True
   B. False

EXAM KEY F2-5.6

1. A
2. B
3. B
4. B
5. B
6. A
7. A
8. A
9. A
10. B

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (6800)

F2-6: PROGRAMMING ALGORITHMS

TASK: Perform basic programming using algorithms.

PURPOSE: In the repair of microprocessor based devices you must understand the complete operation of the system in a very short time. There are hardware and software tools available to aid in the understanding of a system. This learning guide will explain the terms and processes necessary to use algorithms in the understanding of microprocessor machine language programs.

OBJECTIVE: Given a written examination, you will be able to identify the correct information to perform basic programming using algorithms. To master this task you must score at least 80% on the written examinations and laboratory exercises.

ESTIMATED CLASS TIME: 5 HOURS

PROGRAMMING ALGORITHMS

LEARNING STEPS

F2-6

READ:	Information Sheet F2-6.1, "Algorithms." Material on computer algorithms.
READ:	Information on program algorithms from the following resource list.
COMPLETE:	Activity Sheet F2-6.2, "Algorithms."
REVIEW:	Information Sheet F2-6.1, and Activity Sheet F2-6.2.
COMPLETE:	Laboratory performance on using algorithms in the writing, entering and running programs on the microprocessor trainer. Contact your instructor.
COMPLETE:	Performance Checklist F2-6.3.
COMPLETE:	Written Exam F2-6.4 for mastery of this task.

PROGRAMMING ALGORITHMS

RESOURCES

F2-6

1. Brunner, INTRODUCTION TO MICROPROCESSORS (Reston, 1982).
2. Gilmore, INTRODUCTION TO MICROPROCESSORS.
3. Motorola, MICROPROCESSOR APPLICATION MANUAL.
4. Heathkit, MICROPROCESSORS.
5. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS.
6. Branko and Sopucek, MICROPROCESSORS AND MICROCOMPUTERS.
7. Goody, THE VERSATILE MICROCOMPUTER (SRA, 1982).
8. Additional references as available.

REQUIRED EQUIPMENT

6800 Microprocessor trainer
Oscilloscope
Digital Multimeter (DMM)

INFORMATION SHEET

F2-6.1

ALGORITHMS

All microprocessors are required to do arithmetical computations ranging from simple addition to intrinsic functions. Most 8-bit microprocessors do not have hardware capability to do more than add two 8-bit binary numbers. They subtract by making a positive number negative and adding the two numbers. The more complex computations such as multiplication and division are done in software using certain algorithms. An algorithm is a step-by-step procedure for accomplishing a particular task or function. An algorithm is often a subroutine that is called upon to perform such functions.

If you were to multiply 2 times 6 what would you do? If you have learned the multiplication table, you just know the answer. But how was that table developed? To multiply 2 times 6 add either 2 to itself 6 times or 6 to itself twice. The result is the same, 12. So multiplication is nothing more than repeated addition. Although this seems a very slow way to arrive at the result, especially when the two numbers are very large, it is exactly how a microcomputer would solve the problem. Even though many a problem may require additions, the microcomputer can add two numbers in 1/1000000 of a second.

Even with such high speed it is necessary to develop very short algorithms (programs) to prevent the computer from being "too slow." To enable these algorithms to be as compact and fast as possible, new instructions are used along with the current instructions. These instructions simplify the algorithms and speed up the computational process. Recent advances have been made in microprocessors, and some new 16/32 bit microprocessors contain multiply and divide instructions. These machines are much faster than those that must use software algorithms. Where speed is very critical, special dedicated microprocessors are designed as arithmetic chips and can do computational functions including the intrinsic functions (sine, cosine, etc.) in 1/1000000 of a second or less.

The following is an example of an algorithm that multiplies a 16-bit unsigned number located in memory locations 0021_{16} and 0022_{16} by an 8-bit unsigned number in accumulator A. The result is stored in memory locations 0023_{16} and 0024_{16}. The program is not re-entrant. This means that the program can not be interrupted and shared by another program as would be necessary in a multiuser and/or multitasking system. Also all registers are used without being saved. The multiplier is destroyed and the multiplicand is preserved.

There is no check made for an overflow condition. The numbers must be checked before being entered into the memory locations and accumulator A. This program will also do single precision multiplication by setting the MSB of the multiplicand to zero. The program may also be used for signed multiplication.

UNSIGNED SINGLE-PRECISION MULTIPLICATION

```
MEMORY  CONTENTS   LABEL   OPERAND  VALUES   COMMENTS
-----------------------------------------------------------------

0000    CE 00 08   START   LDX       #8  Initialize index register
0003    5F                 CLRB          clear accumulator B
0004    D7 23      RSLT1   STAB     #23  Clear 1st byte of result
0006    D7 24      RSLT2   STAB     #24  Clear 2nd byte of result
0008    78 00 24   LOOP    ASL      #24  Shift partial answer
000B    79 00 23           ROL      #23
000E    48                 ASLA         Shift multiplier bit in
                                             ACC A
000F    24 OC              BCC      #OC  Branch if carry
0011    26 22      NUMB2   LDAB     #22  Get LSB of mutliplicand
0013    DB 24              ADDB     #24  Addd resutl toLSB
0015    D7 24              STAB     #24  Partial answer
0017    D6 21      NUMB1   LDAB     #21  Get MSB of multiplicand
0019    D9 23              ADCB     #23  Add MSB
001B    D7 23              STAB     #23  Find partial answer
001D    09         LPEND   DEX           Decrement index register
001E    26 E8              BNE      #E8  Branch back to loop
0020    3E                 WAI           Wait for interrupt
```

The development of a software algorithm to perform any function is often a difficult task, and is often aided by the use of a flowchart. Along with the flowchart it is necessary to document the program with comments and other useful information explaining how the task is being accomplished.

ACTIVITY SHEET

F2-6.2

ALGORITHMS

1. Write simple programs that can perform computer arithmetic, including multiplication and division, using repeated addition and subtraction.
2. Write simple programs that can add two BCD numbers.
3. Explain the purpose of flowcharting and documentation.

PROGRAM: ELECTRONICS

TASK: PROGRAMMING ALGORITHMS

TASK #: F2-6.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Perform basic programming using algorithms.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

PROGRAMMING ALGORITHMS

F2-6.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required data recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

1637

PROGRAMMING - ALGORITHMS

EXAM F2-6.3

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on programming algorithms. Each of the statements is true or false. Place the letter associated with the correct choice (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F2-6.4

1. Most 8-bit microprocessors do not have hardware multiply capabilities.

   A. True
   B. False

2. Most 8-bit microprocessors use BCD for all math operations.

   A. True
   B. False

3. The ALU always adds numbers as if they were signed binary numbers.

   A. True
   B. False

4. The use of the ADC instruction is to simplify multiple-precision arithmetic.

   A. True
   B. False

5. The SBC instruction is a subtract with borrow instruction.

   A. True
   B. False

6. The ASL instruction can be used to pack two ASCII characters into a single byte.

   A. True
   B. False

7. The carry flag can be thought of as an extension of the accumulator.

   A. True
   B. False

8. Any binary number can be multiplied by two simply by shifting the number one bit to the left.

   A. True
   B. False

9. Most 8-bit microprocessors manipulate data in the form of binary coded decimal numbers.

   A. True
   B. False

10. When an ADC instruction follows an ADD instruction, a 1 is added to the LSB of the sum, if the carry bit was set to 1 before the ADC instruction was executed.

   A. True
   B. False

EXAM KEY F2-6.4

1. A
2. B
3. B
4. A
5. A
6. B
7. A
8. A
9. B
10. A

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (6800)

F2-7: 6800 MPU ARCHITECTURE

TASK:	Diagram and define the architecture of the 6800 microprocessor.
PURPOSE:	To understand microprocessors you must be able to diagram and define the architecture of a typical microprocessor. This learning guide will explain the terms and processes necessary to be able to diagram and define the architecture of a typical microprocessor.
OBJECTIVE:	Given a written examination, you will be able to identify the information necessary to diagram and define the architecture of a typical microprocessor. To master this task you must score at least 80% on the written examinations and laboratory exercises.

ESTIMATED CLASS TIME: 5 HOURS

6800 MPU ARCHITECTURE

LEARNING STEPS

F2-7

READ: Information Sheet F2-7.1, "6800 MPU." Material on 6800 microprocessor architecture.

READ: Information on 6800 architecture from the following resource list.

COMPLETE: Activity Sheet F2-7.2, "6800 MPU."

REVIEW: Information Sheet F2-7.1 and Activity Sheet F2-7.2.

COMPLETE: Laboratory performance on microprocessor architecture. Contact your instructor.

COMPLETE: Performance Checklist F2-7.3.

COMPLETE: Written Exam F2-7.4 for mastery of this task.

6800 MPU ARCHITECTURE

RESOURCES

F2-7

1. Brunner, INTRODUCTION TO MICROPROCESSORS (Reston, 1982).
2. Gilmore, INTRODUCTION TO MICROPROCESSORS.
3. Motorola, MICROPROCESSOR APPLICATION MANUAL.
4. Heathkit, MICROPROCESSORS.
5. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS.
6. Branko and Sopucek, MICROPROCESSORS AND MICROCOMPUTERS.
7. Goody, THE VERSATILE MICROCOMPUTER (SRA, 1982).
8. Additional references as available.

REQUIRED EQUIPMENT

6800 Microprocessor Trainer
Oscilloscope
DMM

INFORMATION SHEET

F2-7.1

6800 MPU

To understand the operation and programming of the Motorola 6800 MPU it is necessary to develop a programming model. This programming model is shown below.

PROGRAMMING MODEL OF THE 6800 MPU

```
7               0 7              0
________________  _______________
|    ACCB       | |    ACCA      | Accumulator
________________  _______________

15                               0
_________________________________
|              IX                | Index Register
_________________________________

15                               0
_________________________________
|             PC               | Program  Counter
_________________________________

15                               0
_________________________________
|              SP                | Stack Pointer
_________________________________

7               0
________________
:1:1:H:I:N:Z:V:C:  Condition Code Register
________________

 ^ ^ ^ ^ ^ ^ ^ ^
 : : : : : : : ---- Carry Register
Not Used ----- : : : : ------ Overflow
Always 1       : : : -------- Zero
               : : ---------- Negative
               : ------------ Interrupt
               -------------- Half Carry (from bit 3)
```

INFORMATION SHEET F2-7.1 CONT'D.

The 6800 MPU has two accumulators, A and B, each with its own group of instructions. It also has a 16-bit program counter. Enabling it to specify $65,535_{10}$ different memory addresses. The index register is a special-purpose 16-bit register. This register allows a powerful address mode called indexed addressing. Another special-purpose 16-bit register is the stack pointer. This pointer enables the MPU to use a section of RAM as a last in, first out memory. The last block is the condition code register. This is an 8-bit register of which the two most significant bits, B7 and B6, are always 1. The other bits, B5 through B0, are the status flags. When the associated bit is a 0, the flag is cleared. The flag is set when the associated bit is a 1.

Along with this architecture the 6800 has an instruction set consisting of 72 instructions which when combined with the various addressing provide 197_{10} different opcodes to which the MPU will respond. These instructions are grouped into six categories: data handling instructions, logic instructions, data test instructions, index register and stack pointer instructions, branch instructions, and condition code register instructions.

There are six addressing modes available for the 6800: inherent, immediate, direct, relative, extended, and indexed. Of these instructions, the extended and indexed can address any memory location from anywhere in the memory map. Many programs contain numbers that remain constant for any set of variables. The 6800 is equipped with an addressing mode to simplify the use of constants. The immediate addressing allows the programmer to include the constant in the program. In this mode of addressing the actual data is listed instead of an address. The indexed mode is the most powerful mode available to the 6800 MPU.

These are all of the available features of the 6800 microprocessor. Newer additions to the family such as the 6809, 68000, 68010 and the 68020 have additional features which are beyond the scope of this unit.

ACTIVITY SHEET

F2-7.2

6800 MPU

1. Draw a programming model of the 6800 MPU.
2. Explain the function of each block in a simplified block diagram of the MPU.
3. Using the available information, explain the instructions of the 6800 introduced in this unit.
4. Write a program that demonstrates the use of the 6800 instructions as discussed in this unit.

PROGRAM: ELECTRONICS

TASK: 6800 MPU ARCHITECTURE

TASK #: F2-7.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Diagram and define the architecture of the 6800 microprocessor.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

6800 MPU ARCHITECTURE

F2-7.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required data recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

6800 MPU ARCHITECTURE

EXAM F2-7.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on 6800 MPU architecture. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, 80%).

EXAM F2-7.4

1. What is the largest unsigned number that can be stored in an 8-bit memory location?

   A. 255_{10}
   B. F_{16}
   C. 127_{10}
   D. $65,535_{10}$

2. In a 6800 microprocessor, the program counter ___________.

   A. holds the data that is to be placed on the data bus
   B. contains the address of the next instruction to be executed
   C. holds the opcode while it is being decoded
   D. contains the address at which the next data byte will be stored

3. The operations that the computer can be told to perform are called ___________.

   A. instructions
   B. code
   C. bus
   D. programs

The circuit in the microprocessor that performs arithmetic and logic operations is called the ___________.

   A. arithmetic logic unit
   B. logic analyzer
   C. accumulator
   D. random access memory

5. The result of an arithmetic operation is held in the ___________.

   A. memory
   B. accumulator
   C. data register
   D. index register

6. Which circuit in the MPU determines the memory location from which the next byte of information will be taken?

   A. accumulator
   B. address register
   C. program counter
   D. data register

7. Which flag is tested by the BMI (branch if minus) instruction?

   A. H
   B. N
   C. Z
   D. V

8. The size of the 6800's program counter is __________.

   A. 4-bits
   B. 8-bits
   C. 16-bits
   D. 24-bits

9. Extended addressing requires an address size of __________.

   A. 4-bits
   B. 8-bits
   C. 16-bits
   D. 24-bits

10. The most powerful addressing mode available on the 6800 is __________.

   A. direct
   B. extended
   C. relative
   D. indexed

EXAM KEY F2-7.4

1. A
2. B
3. A
4. A
5. B
6. C
7. B
8. C
9. C
10. D

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (6800)

F2-8: ADDITIONAL 6800 ADDRESSING MODES

TASK:	Write, enter, verify and run a machine language program using additional 6800 addressing modes.
PURPOSE:	To understand microprocessors you must be able to write, enter, verify and run machine language programs using all of the 6800 addressing modes. This learning guide will explain the terms and processes necessary to be able to write, enter, verify and run machine language programs using the last of the 6800 addressing modes.
OBJECTIVE:	Given a written examination, you will be able to identify the information necessary to write, enter, verify and run machine language programs using additional 6800 addressing modes. To master this task you must score at least 80% on the written examinations and laboratory exercises.

ESTIMATED CLASS TIME: 5 HOURS

ADDITIONAL 6800 ADDRESSING MODES

LEARNING STEPS

F2-8

READ:	Information Sheet F2-8.1, "Addressing Modes." Material on addressing modes.
READ:	Information on addressing modes in one or more of the following references.
COMPLETE:	Activity Sheet F2-8.2, "Addressing Modes."
REVIEW:	Information Sheet F2-8.1, and Activity Sheet F2-8.2
COMPLETE:	Laboratory performance on addressing modes. Contact your instructor.
COMPLETE:	Performance checklist F2-8.3.
COMPLETE:	Written Examination F2-8.4 for mastery of this task.

ADDITIONAL 6800 ADDRESSING MODES

RESOURCES

F2-8

1. Brunner, INTRODUCTION TO MICROPROCESSORS (Reston, 1982).
2. Gilmore, INTRODUCTION TO MICROPROCESSORS.
3. Motorola, MICROPROCESSOR APPLICATION MANUAL.
4. Heathkit, MICROPROCESSORS.
5. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS.
6. Branko and Sopucek, MICROPROCESSORS AND MICROCOMPUTERS.
7. Goody, THE VERSATILE MICROCOMPUTER (SRA, 1982).
8. Additional references as available.

REQUIRED EQUIPMENT

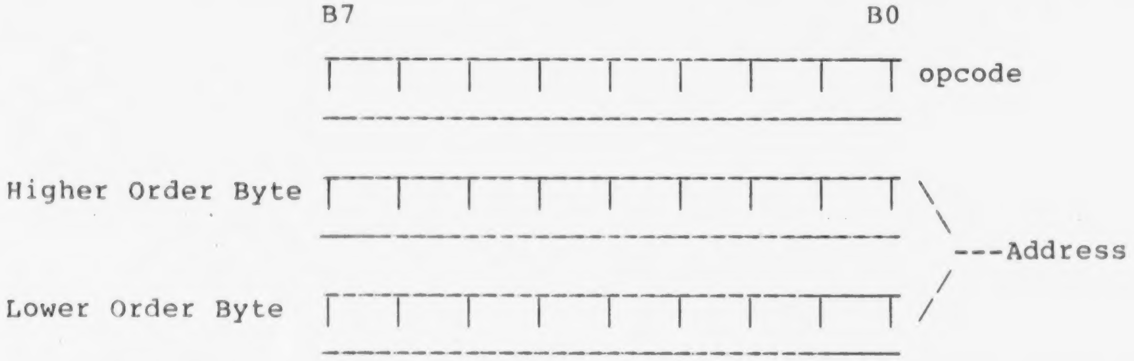
6800 Microprocessor Trainer
Oscilloscope
DMM

INFORMATION SHEET

F2-8.1

ADDRESSING MODES

Extended addressing is similar to direct addressing. Direct addressing uses an 8-bit operand and thus is limited to the first 256_{10} bytes of memory. Extended addressing uses a two byte, 16-bit, operand and is capable of addressing any one of the 65,536 memory locations. The format used for extended addressing is:



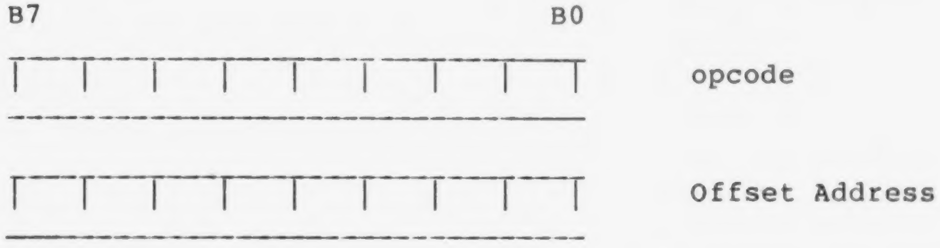
Let's assume that you wish to load the operand at memory location $FC84_{16}$ into accumulator A. The following instructions accomplish this:

B6	Opcode for LDAA extended
FC	Higher order address
84	Lower order address

The most powerful addressing mode available within the 6800 is the indexed addressing mode. This mode makes use of the 16-bit index register of the 6800 MPU. As this register is incremented or decremented, it becomes a 16-bit pointer and can point to any address in memory. To this pointer it is possible to add an 8-bit offset.

Just as in other addressing modes, indexed addressing specifies the location of data to be used by an instruction. Most memory and accumulator operations can use the indexed mode. The data address is determined as a combination of the contents of the index register and an offset that follows the instruction. Because the index register is 16-bit, indexed instructions can address the entire memory space of the 6800. Since it is a two-byte or 16-bit register, the index register requires two bytes of memory space when saved into memory or placed on the stack.

The instruction format of the indexed addressing mode is as follows:



The instruction consists of two bytes, the opcode and the offset address. The offset address is added to the index register to determine the actual address of the data. The program below illustrates the application of indexed addressing.

For example, if it is necessary to clear 100_{16} memory locations starting at 8000_{16}

```
4F        Opcode for CLRA
CE        Opcode for LDX immediate
80        Higher order byte
00        Lower order byte
A7        Opcode for STAA indexed <----
00        Offset is 00                 |
08        Opcode for INX               |
8C        Opcode for CPX               |
81        Higher order byte            |
00        Lower order byte             |
26        Opcode for BNE               |
F8        Branch destination  >-------
3E        Opcode for wait
```

All the instructions available to a microprocessor are known as the instruction set. Items available in the instruction set for each instruction are:

-operation
-mnemonic
-addressing modes
-Boolean operation
-condition code status

Within each addressing mode, is given the opcode for the instruction, the number of machine cycles required to complete the instruction, and the number of bytes to hold the opcode and operand.

ACTIVITY SHEET

F2-8.2

ADDRESSING MODES

1. Write and execute simple programs that use indexed and extended addressing modes.

2. Using available information, find the opcode, number of MPU cycles, number of bytes, and effects on the condition code flags for the instructions introduced in this unit.

PROGRAM: ELECTRONICS

TASK: ADDITIONAL 6800 ADDRESSING MODES

TASK #: F2-8.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Write, enter, verify and run a machine language program using additional 6800 addressing modes.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

ADDITIONAL 6800 ADDRESSING MODES

F2-8.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required data recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

ADDITIONAL 6800 ADDRESSING MODES

EXAM F2-8.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on additional 6800 addressing modes. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, 80%).

EXAM F2-8.4

1. Which addressing mode is best for searching a list of numbers?

   A. direct
   B. extended
   C. indexed
   D. relative

2. Which of the following operations can **not** be performed directly on a byte in memory using a single instruction?

   A. increment
   B. shift left arithmetically
   C. test for zero
   D. compare

3. A disadvantage of direct addressing is that the operand must be in the first ___________ bytes of memory.

   A. 256_{10}
   B. 256_{2}
   C. 100_{10}
   D. 100_{16}

4. Extended addressing can address __________ bytes of memory.

   A. FF_{16}
   B. 256_{10}
   C. 10000_{10}
   D. $FFFF_{16}$

5. The second byte of an indexed addressing instruction is called the __________ address.

   A. opcode
   B. operand
   C. offset
   D. indexed

6. Indexed addressing requires __________ bytes for each instruction.

   A. 1
   B. 2
   C. 3
   4. 4

7. The advantage of direct addressing is that only __________ bytes are required for each instruction.

A. 1
B. 2
C. 3
D. 4

8. A disadvantage of indexed addressing is that it must use the __________ register.

9. A disadvantage of extended addressing is that __________ bytes are required for each instruction.

A. 1
B. 2
C. 3
D. 4

10. The last byte of an extended addressing instruction is ____________.

A. always set to zero
B. not needed
C. the higher byte of the operand
D. the lower byte of the operand

EXAM KEY F2-8.4

1. C
2. D
3. A
4. D
5. C
6. B
7. B
8. A
9. C
10. D

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (6800)

F2-9: 6800 STACK OPERATION

TASK: Explain and demonstrate the operation of a stack in a 6800 microprocessor.

PURPOSE: One of the operations necessary on all microprocessors is stack operation. To understand microprocessors you need to write, enter, verify and run machine language programs using the stack. This learning guide will explain the terms and processes necessary to be able to write, enter, verify and run machine language programs using the stack.

OBJECTIVE: Given a written examination, you will be able to explain and demonstrate the operation of the stack in a 6800 microprocessor. To master this task, you must score at least 80% on the written examination and laboratory exercises.

ESTIMATE CLASS TIME: 5 HOURS

6800 STACK OPERATION

LEARNING STEPS

F2-9

READ: Information Sheet F2-9.1, "6800 Stack Operation." Material on 6800 stack operation.

READ: Information on 6800 stack operation in one or more of the references.

COMPLETE: Activity Sheet F2-9.2, "6800 Stack."

READ: Information Sheet F2-9.3, "6800 Subroutines." Material on subroutines.

COMPLETE: Activity Sheet 9.4, "6800 Subroutines."

REVIEW: Information Sheets F2-9.1, F2-9.3, and Activity Sheets F2-9.2, F2-9.4.

COMPLETE: Laboratory performance on 6800 stack operation. Contact your instructor.

COMPLETE: Performance checklist F2-9.5.

COMPLETE: Written examination F2-9.6 for master of this task.

6800 STACK OPERATION

RESOURCES

F2-9

1. Brunner, INTRODUCTION TO MICROPROCESSORS (Reston, 1982).
2. Gilmore, INTRODUCTION TO MICROPROCESSORS.
3. Motorola, MICROPROCESSOR APPLICATION MANUAL.
4. Heathkit, MICROPROCESSORS.
5. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS.
6. Branko and Sopucek, MICROPROCESSORS AND MICROCOMPUTERS.
7. Goody, THE VERSATILE MICROCOMPUTER (SRA, 1982).
8. Additional references as available.

REQUIRED EQUIPMENT

6800 Microprocessor Trainer
Oscilloscope
DMM

INFORMATION SHEET

F2-9.1

6800 STACK OPERATION

Microprocessors often make use of a special memory area called the **stack.** Numbers are placed in in the stack in a "last-in first-out" configuration. As subsequent numbers are "pushed" onto the stack, the stack pointer increments automatically and always contains the address of the top of the stack. When it becomes necessary to get an item back, the microprocessor reads from the memory location pointed to by the stack pointer and "pops" numbers off the stack in reverse order loaded.

There are two types of stacks, cascade stack and memory stack. Both of these stacks are memory locations. Cascade stacks are often located in the actual MPU itself. Such a stack is very expensive and usually provides only 8 to 16 locations. In this type of stack the number to be stored is loaded into the first memory location. When a second number needs to be stored, it too is stored at the first memory location, after the original information has been transferred to the second location. This process repeats for each additional number to be saved. If the stack has only 8 registers, and 9 numbers are pushed onto the stack, the very first number will be moved from the eighth register to the ninth register. Because there is no ninth register, the number is lost. Numbers must come off the stack in reverse order. The process destroys (erases) each number as it is read from the stack.

The memory stack works on a similar principle, except that it can be much larger. The memory stack is simply a series of locations in the microprocessor's memory map reserved for these numbers. The operation of the memory stack is different than the cascade stack in the MPU. It is not possible to quick shift up or down in a memory stack as was done in the cascade stack. Instead, a pointer is used to keep track of the next empty location to be filled. As a number is written, it is placed at the location pointed to by the stack pointer. When it becomes necessary to retrieve the number, the stack pointer will identify the correct position. Only the stack pointer count is being changed; thus the actual contents of the stack remain after being read. This is useful in some instances where it may be necessary to back up and recover or repeat an instruction or group of instructions.

Because the stack pointer is simply a register within the MPU, it is possible to change the number in it. This allows the stack to be manipulated quickly and easily by the program in the microprocessor. The location of stack is determined by the initialization of the stack pointer register.

INFORMATION SHEET F2-9.1 CONT'D.

There are several instructions to manipulate the information for the stack and the stack pointer. The two most often used instructions are the PUSH and PULL instructions. These instructions allow the programmer to place the contents or a register on the stack and get it back at a later date. Also available are instructions that allow the contents of the stack pointer to be changed.

The stack pointer can be loaded from or stored in memory using LDS and STS; incremented or decremented using INS and DES; or transferred to or from the indexed register using TSX and TXS. Changing the stack pointer should not be done unless the programmer is 100% sure of what is being done. You will discover in a later unit that the stack is necessary for the proper servicing of interrupts.

Because the stack is in memory, it is possible to have more than one. To run two or more programs with a single MPU, just interrupt the MPU and have it resume running with the information from a different stack. It is then possible to return to the original program by reversing the process.

ACTIVITY SHEET

F2-9.2

6800 STACK OPERATION

1. Explain the difference between a cascade stack and a memory stack.

2. Explain the operations performed by each of the instructions that operate on the stack.

3. Define stack, stack pointer.

INFORMATION SHEET

F2-9.3

6800 SUBROUTINES

By using the stack it is possible to execute more than one program on the 6800. This is accomplished in various ways. The most common way is to use subroutines.

The inputing of a character from a keyboard is an example of a subroutine. Each time a key is pressed, the microprocessor should input the correct character into its memory. When a program is written that must get a character from the keyboard, all it has to do is use the subroutine. Most microprocessors have an input character routine (INCH), and an output character routine (OUCH).

The in and out routines are two common subroutines that were written by the systems programmer and are in the ROM. Not all subroutines are in ROM. Many times it is necessary to write the necessary subroutines to accomplish a desired task. These subroutines are placed within the main program itself, though they are usually located at the end of the program.

When a subroutine is called from the main program, the contents of the various registers need to be saved so that the microprocessor can resume execution of the main program at the exact point where it was called. It is possible to load the accumulators and store them in memory with the contents of all the registers, but this is very slow and requires a large amount of code. Instead, the subroutine call automatically saves the contents of the program counter on the stack. When the routine is finished, the contents of the program counter are restored and the main program continues.

If it is necessary to save the contents of any of the other registers, they must be placed on the stack as the first instructions within the subroutine. When the subroutine is finished, its last instructions will be to restore the contents of the previously saved registers. It is possible for subroutines to contain subroutines. This process is called nested subroutines. The deeper the nesting of the subroutines, the more memory required for the stack.

The instructions that operate on subroutines are the branch subroutine (BSR), the jump subroutine (JSR) and the return from subroutine, (RTS). The calling instructions of branch subroutine and jump subroutine save the program counter on the stack when executed. The return from subroutine instructions restore the program counter from the stack. The BSR instruction can only jump to an address within the range of $+127_{10}$ to -128_{10}. Remember that branches are program counter relative. This allows the program containing the subroutine branch to be position independent. Position independence allows the code to be rapidly transported among various 6800 systems, saving programming time and money.

ACTIVITY SHEET

F2-9.4

6800 SUBROUTINES

1. Define subroutine, nested subroutine.

2. Write and execute simple programs that can store and retrieve data, using the stack.

3. Write and execute simple programs that use nested subroutines.

4. Write simple programs that demonstrate the use of subroutines.

PROGRAM: ELECTRONICS

TASK: 6800 STACK OPERATION

TASK #: F2-9.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Explain and demonstrate the operation of a stack in a 6800 microprocessor.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

6800 STACK OPERATION

F2-9.5

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required data recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

1676

6800 STACK OPERATION

EXAM F2-9.6

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on 6800 stack operations. Each of the statements is true or false. Place the letter associated with the corerect choice (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F2-9.6

1. Cascade stacks usually have more memory locations than memory stacks.

   A. True
   B. False

2. The main function of a stack is to hold the results of logic operations.

   A. True
   B. False

3. It is possible to manipulate the stack pointer of a memory stack.

   A. True
   B. False

4. The cascade stack does not need a stack pointer.

   A. True
   B. False

5. The PUSH and PULL instructions are used to place and remove numbers from a memory stack.

   A. True
   B. False

6. When information is read from a memory stack, the information is erased.

   A. True
   B. False

7. A stack will overflow when the data is placed into it too rapidly.

   A. True
   B. False

8. It is possible to place all the registers of the 6800 MPU on the stack.

   A. True
   B. False

9. The 6800 MPU uses a cascade stack.

   A. True
   B. False

10. The stack pointer is usually located in the memory map of the microprocessor.

    A. True
    B. False

EXAM KEY F2-9.6

1. B
2. B
3. A
4. A
5. A
6. B
7. B
8. A
9. B
10. B

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (6800)

F2-10: 6800 INPUT-OUTPUT

TASK: Explain and demonstrate input and output operations using the 6800 microprocessor.

PURPOSE: Microprocessor input-output is necessary in all systems. This learning guide will explain the terms and processes necessary to understand the input-output of the microprocessor and related programs.

OBJECTIVE: Given a written examination, you will be able to explain and demonstrate the input and output processes using the 6800 microprocessor. To master this task you must score at least 80% on the written examinations and laboratory exercises.

ESTIMATED CLASS TIME: 5 HOURS

6800 INPUT-OUTPUT

LEARNING STEPS

F2-10

READ:	Information Sheet F2-10.1, "6800 Input-Output." Material on 6800 input-output operations.
READ:	Information on 6800 input-output operations in one or more of the references.
COMPLETE:	Activity Sheet F2-10.2, "6800 Input-Output."
READ:	Information Sheet F2-10.3, "6800 Interrupts." Material on 6800 vector operations.
COMPLETE:	Activity Sheet 10.4, "6800 Interrupts."
REVIEW:	Information Sheets F2-10.1, F2-10.3, and Activity Sheets F2-10.1, F2-10.4.
COMPLETE:	Laboratory performance on 6800 input-output operations. Contact your instructor.
COMPLETE:	Performance Checklist F2-10.5.
COMPLETE:	Written Examination F2-10.6 for mastery of this task.

6800 INPUT-OUTPUT

RESOURCES

F2-10

1. Brunner, INTRODUCTION TO MICROPROCESSORS (Reston, 1982).
2. Gilmore, INTRODUCTION TO MICROPROCESSORS.
3. Motorola, MICROPROCESSOR APPLICATION MANUAL.
4. Heathkit, MICROPROCESSORS.
5. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS.
6. Branko and Sopucek, MICROPROCESSORS AND MICROCOMPUTERS.
7. Goody, THE VERSATILE MICROCOMPUTER (SRA, 1982).
8. Additional references as available.

REQUIRED EQUIPMENT

6800 Microprocessor trainer
Oscilloscope
DMM

INFORMATION SHEET

F2-10.1

6800 INPUT-OUTPUT

To serve a useful function, a microprocessor system must be able to communicate with the outside world. The point where information enters or leaves the microprocessor is known as a port. Data received by the microprocessor is called input. Data transmitted by the microprocessor is called output. All microprocessors and microcomputers have input-output ports or I/O ports. It is possible for an input device to be nothing more than a simple switch and the output device could be as simple as a single lamp or LED. At the other extreme, the I/O could be a dozen or more terminals and printers, or other peripheral devices connected to a single microprocessor. Or perhaps the microprocessor might be controlling an entire automated work cell, including a robot.

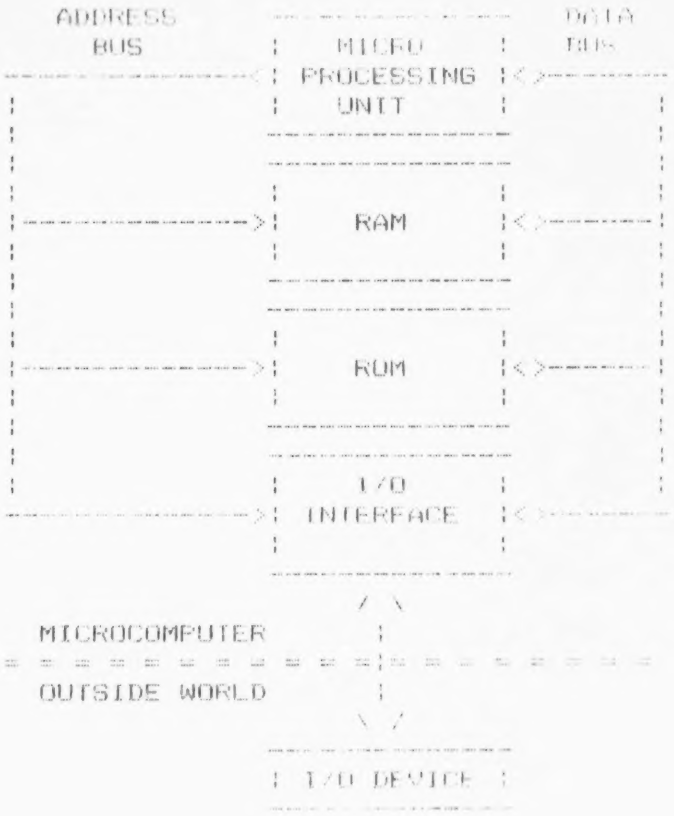
Two different methods have been developed for the handling of I/O operations. In some microprocessors, I/O operations are handled by a separate set of I/O instructions. This type of microprocessor usually has one input and one output instruction. When an instruction is executed, a byte is transferred between the I/O port and a register (usually an accumulator) in the MPU. The I/O device is selected by sending a byte on the address bus. Because a byte is used to select the I/O device, up to 256_{10} devices may be attached to the microprocessor.

The 6800 microprocessor uses a different method for handling I/O operations. All transfers are treated as memory transfers. This is known as memory mapped I/O. Even microprocessors with I/O instructions can bypass those instructions and handle I/O operations as memory transfers. The advantage of using memory mapped I/O is that the attached device is treated as a memory location. This enables the instructions that involve memory operations to be used in data transfer.

Improperly connected peripheral devices could damage or destroy the microprocessor. But the microprocessor and the peripheral device must communicate with each other. The circuitry that accomplishes this is called the I/O interface.

The I/O interface generally contains decoder circuitry to prevent the I/O interface from interfering when data is being transferred between memory and the MPU. In addition it will contain a latch to hold the data until the MPU or peripheral device is ready for the data. Buffers and drivers are also included in the I/O interface to enable the MPU and external devices to communicate properly.

The following is a typical memory map showing how the I/O interface and I/O device are connected to a 6800 MPU. As shown the I/O interface is treated just as a memory location, connected to both the address and data buses. As your studies continue, you will interface the MPU with an I/O interface and I/O devices.


ADDRESS BUS
MICRO PROCESSING UNIT
DATA BUS
RAM
ROM
I/O INTERFACE
MICROCOMPUTER
OUTSIDE WORLD
I/O DEVICE

ACTIVITY SHEET

F2-10.2

6800 INPUT-OUTPUT

1. Define input, output, peripheral device.
2. Describe how the 6800 MPU performs input and output operations, including the status of the necessary buses and signals.

INFORMATION SHEET

F2-10.3

6800 INTERRUPTS

The MPU can handle I/O operations in two ways. First, it can simply look at the I/O port until the information is ready to be received or transmitted. This method is known as program control and is a very easy type of I/O to implement. The problem is that the MPU must waste large amounts of time just waiting.

A more efficient way to handle I/O operations is to use interrupts. Interrupts enable an I/O device to signal the MPU that it is ready to send or receive data. When an interrupt occurs, the MPU suspends its current program and answers the interrupt. When the interrupt is completed, the MPU returns to its previous program.

Here is an analogy that will help to understand the operation of interrupts. You are driving (or riding) in an automobile on your way to get lunch. This is your main program. Suddenly your automobile gets a flat tire. The interrupt has just occurred. In response to the interrupt you stop the execution of your main program and begin the execution of another program. You will have to replace the flat tire. After the flat tire is replaced, the interrupt has been serviced, and you can return to the main program. You can go get lunch. It is possible for an interrupt program to be interrupted. Just visualize what would happen if you found the spare tire flat, and it started to rain. These interrupts would have to be responded to before you could return to the main program. By the time the tire is fixed and you get clean dry clothes it'll be time for dinner!

Just as in the above example, the MPU is capable of handling numerous interrupts. Just as you could ignore the rain and continue to change the tire, the MPU is capable of masking an interrupt request until the MPU wishes to answer it. So that the MPU can resume operation of the previous program, it saves the status of its registers on the stack. When the interrupt program is over, the MPU retrieves the status for the registers and continues its previous program.

There is a set of instructions available in the 6800 associated with interrupts. The RTI instruction is used to return from the interrupt handling program. This removes the information from the stack and restores the MPU's status as it was before the interrupt.

There is an instruction that generates an interrupt from software. This instruction, SWI, is used to test interrupt handling routines. This makes it possible to test programs that are to be interrupted without having to have hardware connected to the microprocessor system.

There are two interrupts available on the 6800 that are used to handle most situations. A non-maskable interrupt, NMI and an interrupt request IRQ. When an interrupt is generated, the microprocessor saves its registers on the stack and then loads the program counter from memory and executes a jump to the instruction located at the specified memory location. The memory locations from which the program counter are loaded in the 6800 are as shown below.

LOCATION	VECTOR
FFFF & FFFE	RESET
FFFD & FFFC	NMI
FFFB & FFFA	SWI
FFF9 & FFF8	IRQ

The vector locations shown above are listed in order of decreasing importance. If an IRQ is generated, the registers are transferred to the stack and the program counter is loaded with the contents of FFF9 and FFF8. The MPU will begin execution at the address stored by the vector. When the interrupt program is finished an RTI return from interrupt instruction is executed and the contents of the MPU are restored from the stack, and the original program continues. If the original program cannot be interrupted, the program can set an IRQ flag that will prevent the processor from responding to the IRQ signal.

The other interrupt, the NMI, executes like the IRQ except for two differences. The first is that it vectors from the address contained in memory locations FFFD and FFFC. The second is that it cannot be masked. Whenever the NMI signal can override the processor, the processor will respond. Only the RESET signal can override the response to an NMI signal.

ACTIVITY SHEET

F2-10.4

6800 INTERRUPTS

1. Define interrupt, interrupt vector, interrupt masking.
2. Explain reset, non-maskable interrupt, interrupt request, software interrupt, return from interrupt, and wait for interrupt as they pertain to the 6800 microprocessor.

PROGRAM: ELECTRONICS

TASK: 6800 INPUT-OUTPUT

TASK #: F2-10.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ____________

TERMINAL PERFORMANCE OBJECTIVE:

Explain and demonstrate input and output operations using the 6800 microprocessor.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

6800 INPUT-OUTPUT

F2-10.5

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required data recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

6800 INPUT-OUTPUT

EXAM F2-10.6

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on 6800 input-output. Each of the statements is true or false. Place the correct answer (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F2-10.6

1. The 6800 MPU has no I/O instructions.

   A. True
   B. False

2. The 6800 MPU can be attached to a maximum of 256 I/O devices.

   A. True
   B. False

3. It is possible to output data from a 6800 MPU's port with the STAA or the STAB instructions.

   A. True
   B. False

4. Two ways to handle I/O operations are with interrupts and timing loops.

   A. True
   B. False

5. Interrupts can be used to signal the MPU that an I/O task is pending.

   A. True
   B. False

6. The non-maskable interrupt is a software generated interrupt.

   A. True
   B. False

7. The "reset interrupt" vectors to addresses FFFE and FFFF.

   A. True
   B. False

8. An interrupt vector is the address of the interrupt service routine.

   A. True
   B. False

9. The software interrupt vector is located at addresses 0000 and 0001.

   A. True
   B. False

10. The response to a reset interrupt automatically places data onto the stack.

    A. True
    B. False

EXAM KEY F2-10.6

1. A
2. B
3. A
4. B
5. A
6. B
7. A
8. A
9. B
10. B

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (6800)

F2-11: 6800 BUS STRUCTURE

TASK:	Diagram, define and explain the bus structure of the 6800 microprocessor.
PURPOSE:	Usually the microprocessor is a small part of a much larger system. The MPU communicates with the other components over groups of conductors or buses. This learning guide will explain the terms and processes necessary to be able to diagram and define the bus structure of a microprocessor.
OBJECTIVE:	Given a written examination, you will be able to identify the information necessary to diagram, define and explain the bus structure of the 6800 microprocessor. To master this task, you must score at least 80% on the written examinations and laboratory exercises.

ESTIMATED CLASS TIME: 5 HOURS

6800 BUS STRUCTURE

LEARNING STEPS

F2-11

READ:	Information Sheet F2-11.1, "6800 Bus Structure." Material on 6800 bus operations.
READ:	Information on 6800 bus operations from one or more of the references.
COMPLETE:	Activity Sheet F2-11.2, "6800 Bus Structure."
REVIEW:	Information Sheet F2-11.1, and Activity Sheet F2-11.2.
COMPLETE:	Laboratory performance on 6800 bus operations. Contact your instructor.
COMPLETE:	Performance checklist F2-11.3. Contact your instructor.
COMPLETE:	Written Examination F2-11.4 for mastery of this task.

6800 BUS STRUCTURE

RESOURCES

F2-11

1. Brunner, INTRODUCTION TO MICROPROCESSORS (Reston, 1982).
2. Gilmore, INTRODUCTION TO MICROPROCESSORS.
3. Motorola, MICROPROCESSOR APPLICATION MANUAL.
4. Heathkit, MICROPROCESSORS.
5. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS.
6. Branko and Sopucek, MICROPROCESSORS AND MICROCOMPUTERS.
7. Goody, THE VERSATILE MICROCOMPUTER (SRA, 1982).
8. Additional references as available.

REQUIRED EQUIPMENT

6800 Microprocessor Trainer
Oscilloscope
DMM

INFORMATION SHEET

F2-11.1

6800 BUS STRUCTURE

A bus is a group of conductors over which information is transferred form one point to another. There are two basic types of buses: unidirectional and bidirectional. A unidirectional bus allows data transfers in one direction only. The address bus of a microprocessor is unidirectional. The microprocessor outputs the necessary address, but never receives an address. A bidirectional bus allows data transfers in either direction, but not in both at the same time. The data bus of a microprocessor is a bidirectional bus. The microprocessor may send or receive data, but not both at the same time.

The figure below represents a typical microprocessor system. Note that there is more than one device connected to the address and data buses. It is necessary to prevent more than one device talking at any one time. It is also necessary to prevent a device from listening when it is not requested.

```
                 CONTROL
    ADDRESS        BUS       ____________
      BUS                   |            |          DATA
                 ------->   |   MICRO    |          BUS
          ------|-------<   | PROCESSING |< >----------
         |      |           |   UNIT     |            |
         |      |           |____________|            |
         |      |            ____________             |
         |      |------->   |    RAM     |< >----------
          ------|------->   |____________|            |
         |      |            ____________             |
         |      |------->   |    ROM     |< >----------
          ------|------->   |____________|            |
         |      |            ____________             |
         |       ------->   |    I/O     |            |
          -------------->   | INTERFACE  |< >----------
      UNIDIRECTIONAL        |____________|  BIDIRECTIONAL
                                 /\
                                 |
                                 \/
                            -------------
                           |  I/O DEVICE |
                            -------------
```

To prevent more than one device responding to the transfer of data, each device, memory location, I/O buffer etc. is encoded with a unique address in the microprocessor's address space. When the microprocessor outputs an address, the address bus is decoded by each device connected to the bus and only the device with the correct match will respond. To reduce the microprocessor drive power requirements, only the device that was chosen will be connected to the bus. This action is possible because the devices connected to the address and data buses are capable of being tri-stated.

Three-state logic devices have a unique third state beyond the normal outputs of 1 and 0. They have an enable/disable connection. When the device is enabled, it functions like a normal logic device. When the device is disabled, it is electrically removed from the bus. It enters a high impedance state and presents no electrical load to the bus.

In addition to the address and data buses, there must be a control bus. The control bus consists of the signals necessary to keep all of the devices functioning at the correct time. Signals on the control bus are read/not write, clock, bus available, phase 0, phase 1, not interrupt request, non-maskable interrupt request, not halt, valid memory address, and data bus enable. Not all of these lines are required in the control bus, and there may even be more depending upon the application.

The 6800 microprocessor is a synchronous device. All activity associated with the microprocessor is timed, using the microprocessor clock. This clock signal is used by the microprocessor to develop various control signals to preserve the timing relationships between the various signal and control lines. One of the major problems with the microprocessor operation is maintaining the timing relationship of the various signals as additional circuitry is added to the microprocessor system.

When the 6800 integrated circuit microprocessor was developed all of the space on the silicon chip was devoted to the circuitry necessary for the MPU architecture. This required other integrated circuits to be used to store the actual program and data for the MPU. The instructions and data move in and out of the MPU on a data bus, a group of 8 conductors that connects the MPU to the outside world. The data bus lines are designated D0 - D7. D0 is the least significant line, and D7 is the most significant line. The direction of data flow over the conductors is determined by the read/write line. The R/W line is a control line usually controlled by the processor. When the read line is high, the MPU expects to receive data from memory. A low on this line is a signal to the outside world that the MPU has placed data on the data bus. Because information may be either entering or leaving the MPU, the data bus is a bidirectional bus as discussed earlier.

The data bus and control bus cannot accomplish data transfer alone; an address bus is required. The address bus carries the address in memory that will be used for the data transfer. As stated earlier, the address bus is a unidirectional bus. The MPU outputs the address for the data transfer. The address bus on the 6800 is 16-bits. This enables the MPU to access 65,536 different memory locations. The processor is capable of addressing 64K of memory. A K is equal to 2^{10}, or 1024_{10}. Newer microprocessors can address even more memory space. The 68000 has 24 address lines. This enables it to address 2^{24}, or 16777216_{10} bytes.

The address lines are numbered in a fashion similar to the data bus. A0 is the least significant bit, and A15 is the most significant bit of the bus. The size of the address bus determines the maximum size of the memory and thus limits the size of the program and data that the microprocessor can execute. There are systems available that can page in and out blocks of 64K of memory. This is accomplished by writing to a memory location that is often located in ROM. Remember, ROM is a read only memory, and does not respond to a write from the microprocessor. Instead, a write-only latch exists at that location. When a binary number of 0, 1, 2, 4, 8, 16, 32, 64, or 128 is written to the latch, one of the 8 pages of 64K memory is accessed. This is popular in multiuser - multitasking applications where each user is given a 64K block of memory. This technique is not needed with the new processors such as the 68000 because they can access a very large memory.

Other types of microprocessors such as the 8080 and 8085 family multiplex the address and data over the same set of conductors. This reduces the number of pins required on the microprocessor chip. The disadvantage is that it is necessary to de-multiplex the data from the bus. This requires additional integrated circuits which make the system slightly more expensive. It also requires additional control signals to signal the peripheral chips whether there is data or address information on the bus.

The control bus of the 6800 controls the sequence of events for the total microprocessor system. The control bus contains such signals as read/write, data bus enable, clock signal (a two phase non-overlapping square wave), interrupt lines, tri-state control line, bus status line, and valid memory address line. Each of the signals may be used by the microprocessor to control the operation of the entire microprocessor system. As covered earlier, the timing of these lines is critical to the operation of the microprocessor system.

ACTIVITY SHEET

F2-11.2

6800 BUS STRUCTURE

1. Define 3-state logic and explain the need for it.
2. Explain the purpose of each of the control lines on the MPU.
3. Explain the timing relationships between the clock signals and the information on the address, data, and R/W lines.
4. Explain the relationship between the number of address lines and the address space of the microprocessor.
5. How many actual memory locations are there in 8K of memory space? How many address lines are needed to access every location?

PROGRAM: ELECTRONICS

TASK: 6800 BUS STRUCTURE

TASK #: F2-11.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Diagram, define and explain the bus structure of the 6800 microprocessor.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

6800 BUS STRUCTURE

F2-11.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required data recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

6800 BUS STRUCTURE

EXAM F2-11.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on 6800 bus structures. Each of the statements is true or false. Place the letter associated with the correct choice (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F2-11.4

1. The address bus of the 6800 is bidirectional.

   A. True
   B. False

2. The 6800 uses memory mapped I/O.

   A. True
   B. False

3. The maximum size for the address bus of the 6800 is 8 bits.

   A. True
   B. False

4. The 6800 is a nonsynchronous device.

   A. True
   B. False

5. The control bus contains the read/not write control line.

   A. True
   B. False

6. Tri-state logic devices have a third or high impedance state.

   A. True
   B. False

7. The buffers on the data lines of a 6800 are bidirectional.

   A. True
   B. False

8. One of the major problems in microprocessor operation is keeping everything in time with everything else.

   A. True
   B. False.

9. All memory devices are always electrically connected to the MPU's data bus.

   A. True
   B. False

10. All memory devices are always electrically connected to the MPU's address bus.

    A. True
    B. False

EXAM KEY F2-11.4

1. B
2. A
3. B
4. B
5. A
6. A
7. A
8. A
9. B
10. A

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (6800)

F2-12: MEMORY AND INTERFACING

TASK:	Prepare software and hardware to perform interface operations with RAM and displays.
PURPOSE:	To understand microprocessor operations you must prepare the software and hardware to perform interface operations with RAM and display. This learning guide will explain the terms and processes necessary to prepare the software and hardware to perform interface operations with RAM and display.
OBJECTIVE:	Given a written examination, you will be able to prepare the software and hardware to perform interface operations with RAM and display. To master this task you must achieve a score equivalent of 80%.

ESTIMATED CLASS TIME: 5 HOURS

MEMORY AND INTERFACING

LEARNING STEPS

F2-12

READ:	Information Sheet F2-12.1, "6800 Interfacing." Material on 6800 interfacing memory.
READ:	Information on 6800 interfacing memory in one or more of the references.
COMPLETE:	Activity Sheet F2-12.2, "6800 Memory Interfacing."
READ:	Information Sheet F2-12.3, "Interfacing Displays to the 6800." Material on 6800 interfacing displays.
COMPLETE:	Activity Sheet 12.4., "Interfacing Displays to the 6800."
REVIEW:	Information Sheets F2-12.1, F2-12.3, and Activity Sheets F2-12.2, F2-12.4.
COMPLETE:	Laboratory performance on 6800 interfacing memory and displays. Contact your instructor.
COMPLETE:	Performance/Product Checklist F2-12.5.
COMPLETE:	Written Examination F2-12.6 for mastery of this task.

MEMORY AND INTERFACING

RESOURCES

F2-12

1. Brunner, INTRODUCTION TO MICROPROCESSORS (Reston, 1982).
2. Gilmore, INTRODUCTION TO MICROPROCESSORS.
3. Motorola, MICROPROCESSOR APPLICATION MANUAL.
4. Heathkit, MICROPROCESSORS.
5. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS.
6. Branko and Sopucek, MICROPROCESSORS AND MICROCOMPUTERS.
7. Goody, THE VERSATILE MICROCOMPUTER (SRA, 1982).
8. Additional references as available.

REQUIRED EQUIPMENT

6800 Microprocessor Trainer
Oscilloscope
DMM

INFORMATION SHEET

F2-12.1

6800 MEMORY INTERFACING

All microprocessor systems require a minimum amount of memory for proper operation. There are usually two types of memory in any system, RAM and ROM. ROM is read only memory. This type of memory has been pre-written with certain programs that are required for the basic operation of the microprocessor. This type of memory is used when the microprocessor is first turned on or the reset button pushed. ROM does not have a read/write line. Instead it has a chip-enable line that "de-tri-states" the data lines so that the chip may be read.

RAM is read and write memory. This type of memory can store information and hold it for retrieval at a later time. There are two basic types of RAM, static and dynamic.

Static RAM is the easiest type of RAM to interface to most microprocessors. Static RAM is organized internally as a matrix of flip-flops. The flip-flops are constructed using six MOSFETs. These flip-flops are capable of being addressed individually or in groups of 4- or 8-bits. When a particular set of flip-flops is addressed, information on the data bus will be transferred to the flip-flops. This information will be retained by the memory until changed by the microprocessor, or the power is turned off.

Dynamic RAM is more difficult to use than static RAM. Dynamic RAM is a matrix of MOSFETs being used to store an electrical charge. The gates of these transistors are charged and the gate capacitance holds the charge. The status of the charge determines whether a 1 or a 0 has been stored on the gate. With only one transistor used to hold the data, dynamic RAMs can be made to hold much more data per chip than static RAMs. Because the charge on the gate is so small, it must be refreshed periodically, approximately every 5 milliseconds. This is done by addressing each location in the memory. If this is not done, the data is lost. This refreshing requires extra circuit complexity. Also dynamic RAM is subject to more soft errors than static. A soft error is a change in a bit, and is caused by nuclear particles changing the charge on the gate of the MOSFET.

An additional disadvantage of dynamic RAM is that the address bus is multiplexed. A 64K-bit dynamic RAM normally requires 16 address pins. Multiplexing requires only 8 pins. This allows the memory to be constructed in smaller packages. However, like refreshing, multiplexing increases the circuit complexity necessary for the memory to function properly.

To fully access every memory location, the memory integrated circuit(s) must be fully decoded. This means that each memory location (of the possible 65535) responds to one and only one unique number on the address bus. ROM is easier to interface because it is a read-only device and does not need bidirectional data bus drivers. RAM needs both bidirectional bus drivers and control from the R/W line.

Static RAM is the easiest to interface because the address buffers and decoders are static, requiring no precharging for operation. The buffers/decoders respond to changes on the address lines and do not latch the input address.

A read from memory requires the microprocessor to send out the appropriate address and control signals at the start of the read cycle. The microprocessor then waits a short period of time, usually one-half or one-quarter of a microsecond; then it latches in the number that is on the data bus. The microprocessor assumes that the number on the data bus is from the memory location that corresponds to the address on the address bus. Should the memory be too slow to respond in the time allowed, the system will fail or operate erratically.

A write to memory follows a similar sequence. The microprocessor sends out the appropriate address and data on the respective buses. The microprocessor waits a fixed amount of time, then, through the control bus, signals the memory that the data is ready. The memory then latches the data into the selected location. As with the read operation, the timing of all the signals is critical.

ACTIVITY SHEET

F2-12.2

6800 MEMORY INTERFACING

1. Explain the difference between static and dynamic RAM.
2. Explain the operation of a simple address decoder.
3. Explain the operation of address multiplexing.
4. Draw a schematic diagram for connecting a 2116 (2K X 8) memory chip to a 6800. Each address space is to be fully decoded from 0000_{16} through $07FF_{16}$.

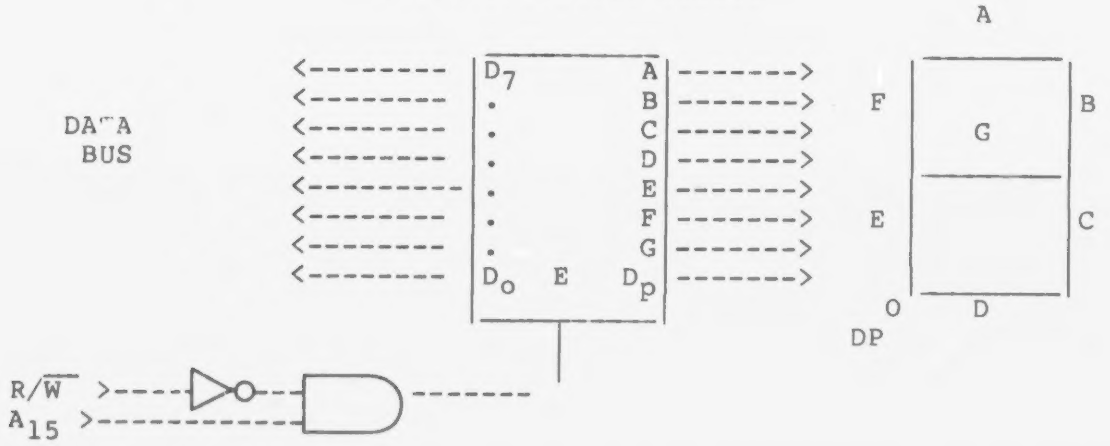
INFORMATION SHEET

F2-12.3

INTERFACING DISPLAYS TO THE 6800

One device that many microprocessor systems are connected to is the 7-segment display. 7-segment displays are available as either common anode or common cathode devices. To light a common anode segment it is necessary to connect that segment to ground through a current limiting resistor. Because of this current requirement it is not possible to directly connect 7-segment displays or similar devices to the address and data buses of the microprocessor. Instead, it is necessary to use latches and/or buffers between the data bus and the 7-segment display. The figure below illustrates a buffer being used to drive a 7-segment display.

8-Bit Tri-State Buffer



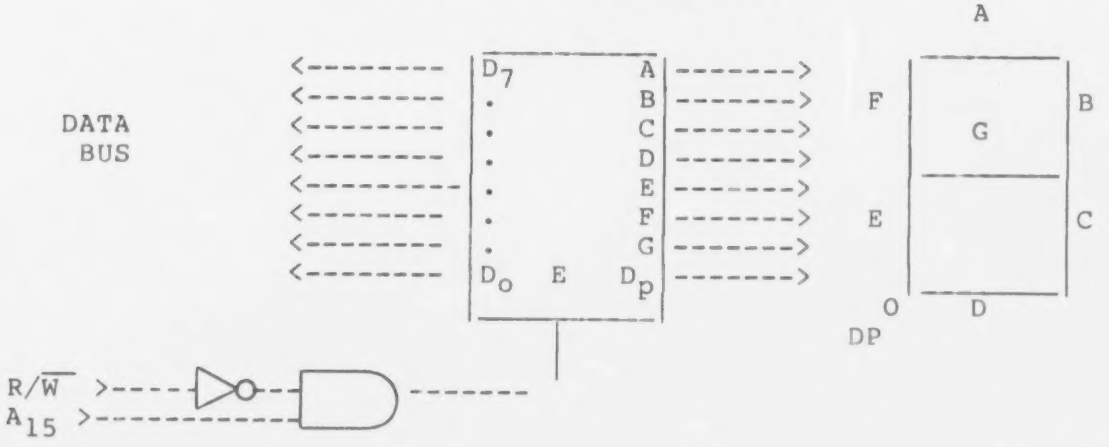
Because of the high speed of the microprocessor it is possible to control the operation of many displays at the same time using decoding and multiplexing. Remember with memory mapped outputs a device can be treated as if it were memory. This enables a 7-segment display to be decoded as if it were memory. Each segment can represent a single bit. Therefore to output any character all that is needed is to write the correct binary number to the corresponding memory location to light up the correct segments to represent the character to be displayed. The table below shows the corresponding segment-bit relationship.

BIT	SEGMENT
0	A
1	B
2	C
3	D
4	E
5	F
6	G
7	DP

The display would not stay lighted very long if it were connected directly (through a buffer) to the data bus. As soon as the MPU finished its write operation, the display would go dark. However, if the display were buffered using latches that were enabled using the read/write line, the display would display the character continuously until the microprocessor rewrites the memory location. The figure below illustrates the use of a latch to retain the data output from the MPU.

To make it easier to interface devices to the 6800 and other microprocessors, manufacturers have developed a "family" of support chips. The 6820 PIA (peripheral interface adapter) is such a chip. The PIA is designed to interface parallel type devices to the 6800 data bus while providing the proper buffering and timing. This device will be covered in a later unit.

8-Bit Tri-State Buffer



ACTIVITY SHEET

F2-12.4

MEMORY AND INTERFACING

1. Explain four different methods by which a MPU can drive 7-segment displays.

2. Explain the problems and benefits of direct connections between the MPU and output devices.

3. Draw a schematic diagram illustrating the construction of 4 multiplexed 7-segment displays connected to a microprocessor data bus.

ACTIVITY SHEET F2-12.4

ANSWER SHEET

1. Independent
   Dynamic
   Latched
   PIA

2. Problems: decoding and complexity
   Advantages: speed of operation and flexibility

3. Trainer dependent

1718

PROGRAM: ELECTRONICS

TASK: MEMORY AND INTERFACING

TASK #: F2-12.5

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ____________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Prepare software and hardware to perform interface operations with RAM and displays.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

MEMORY AND INTERFACING

F2-12.5

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required data recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

1720

MEMORY AND INTERFACING

EXAM F2-12.6

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on memory and interfacing. Each of the statements is true or false. Place the correct answer (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F2-12.6

1. RAM is the abbreviation for random access read and write memory.

   A. True
   B. False

2. Two major types of read and write memory are RAM and ROM.

   A. True
   B. False

3. All memory ICs. have separate input and output pins.

   A. True
   B. False

4. When each memory location in RAM responds to only one address, the RAM is said to be fully decoded.

   A. True
   B. False

5. A memory chip with 256_{10} memory locations needs a minimum of seven (7) address lines (not counting power and handshaking) to operate properly.

   A. True
   B. False

6. A common anode 7-segment display will light a segment when the non-common end of that segment is connected to +5 volts.

   A. True
   B. False

7. All LED-type displays contain only 7 segments and an optional decimal point.

   A. True
   B. False

8. When using latches to drive 7-segment displays directly, there is no need to decode the binary output from the MPU.

   A. True
   B. False

9. For proper operation it is necessary to use a current limiting resistor with each LED in a 7-segment display.

A. True
B. False

10. Multiplexing displays is the process by which more than one character is displayed on each display digit at the same time.

A. True
B. False

EXAM KEY B2-12.6

1. A
2. B
3. B
4. A
5. A
6. B
7. B
8. B
9. A
10. B

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (6800)

F2-13: SWITCH INTERFACING

TASK:	Prepare software and hardware to perform interface operations with switches.
PURPOSE:	To understand microprocessor operation you must prepare the software and hardware to perform interface operations with mechanical contacts. This learning guide will explain the terms and processes necessary to prepare the software and hardware to perform interface operations with mechanical contacts.
OBJECTIVE:	Given a written examination, you will be able to identify the necessary information necessary to be able to prepare the software and hardware to perform interface operations with mechanical contacts. To master this task you must score at least 80% on the written examination and laboratory exercises.

ESTIMATED CLASS TIME: 5 HOURS

SWITCH INTERFACING

LEARNING STEPS

F2-13

READ: Information Sheet F2-13.1, "Interfacing Switches to the 6800." Material on 6800 interfacing mechanical contacts and keyboards.

READ: Information on 6800 interfacing mechanical contacts and keyboards from the following resource list.

COMPLETE: Activity Sheet F2-13.2, "Interfacing Switches to the 6800."

REVIEW: Information Sheet F2-13.1, and Activity Sheet F2-13.2.

COMPLETE: Laboratory performance on 6800 interfacing mechanical contacts and keyboards. Contact your instructor.

COMPLETE: Performance Checklist F2-13.3.

COMPLETE: Written Exam F2-13.4 for mastery of this task.

SWITCH INTERFACING

RESOURCES

F2-13

1. Brunner, INTRODUCTION TO MICROPROCESSORS (Reston, 1982).
2. Gilmore, INTRODUCTION TO MICROPROCESSORS.
3. Motorola, MICROPROCESSOR APPLICATION MANUAL.
4. Heathkit, MICROPROCESSORS.
5. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS.
6. Branko and Sopucek, MICROPROCESSORS AND MICROCOMPUTERS.
7. Goody, THE VERSATILE MICROCOMPUTER (SRA, 1982).
8. Additional references as available.

REQUIRED EQUIPMENT

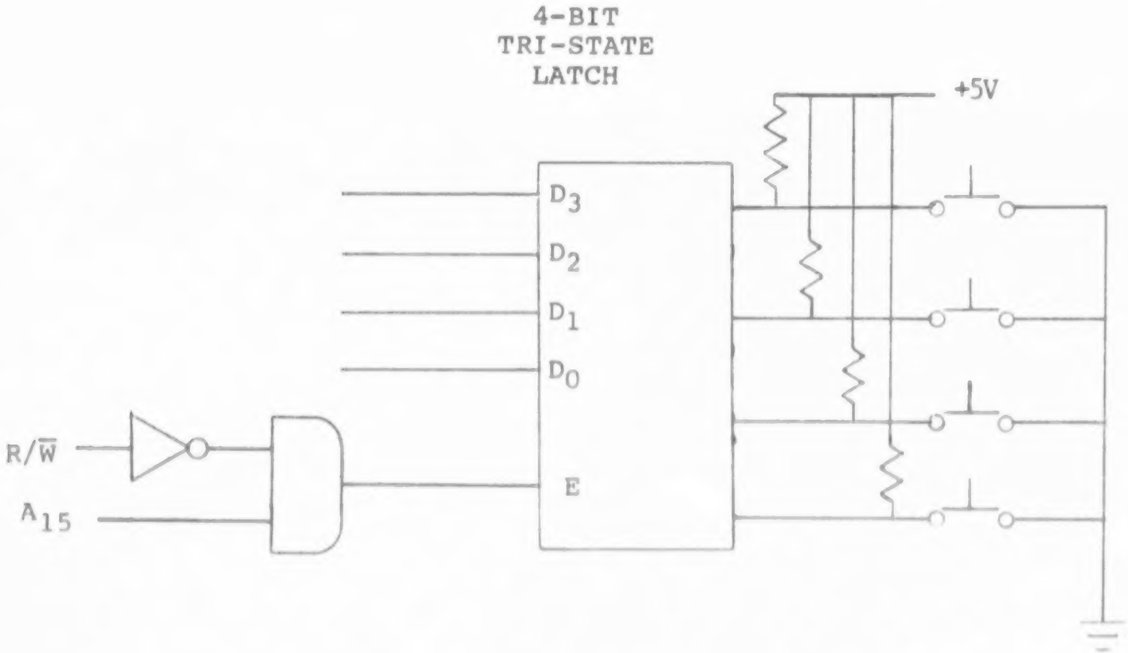
6800 Microprocessor Trainer
Oscilloscope
DMM

INFORMATION SHEET

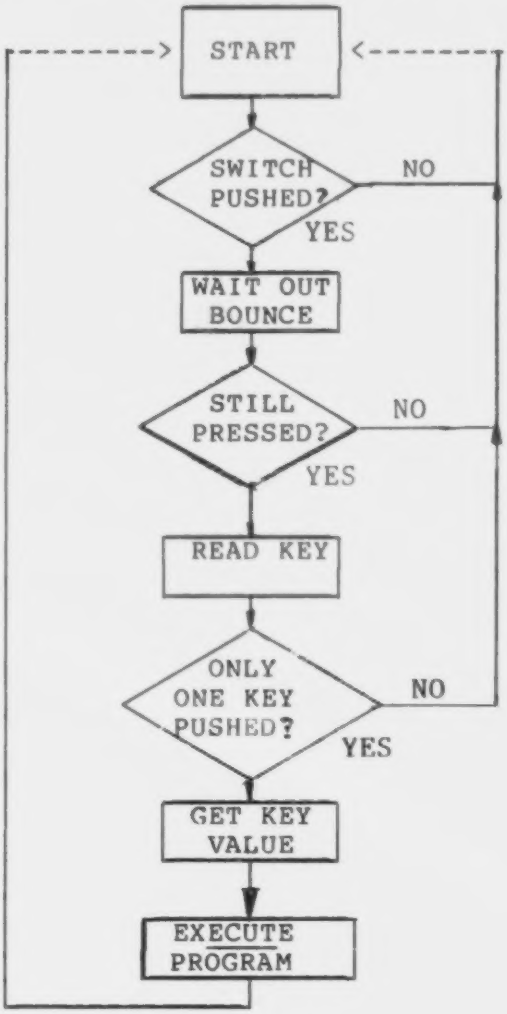
F2-13.1

INTERFACING SWITCHES TO THE 6800

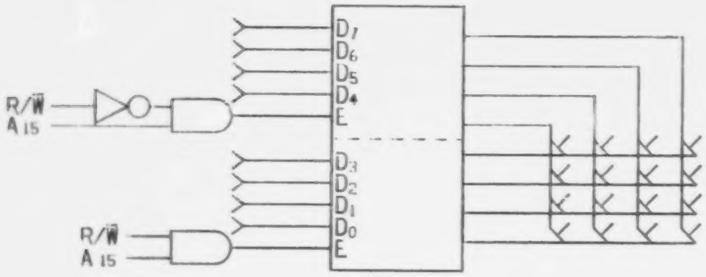
The most popular input device used with microprocessors is the switch. The microprocessor receives much of its necessary information by sensing the condition of one or more switches. These switches may be simple push buttons, or limit switches used in robotics and automated manufacturing work cells, or keyboards used in typewriters and point-of-sale terminals. Where only a few switches need to be interfaced to the microprocessor, they are often connected directly to the data bus, using tri-state logic. To properly interface a device such as a switch to the 6800 MPU, the device must respond as a memory location. The device must have an address and be connected to the control bus, allowing the MPU to control the data flow. It is NOT possible to connect switches directly to the data bus of any microprocessor. The schematic diagram below illustrates the connection of 4 switches to the data bus of a microprocessor using a "tri-stateable" buffer.



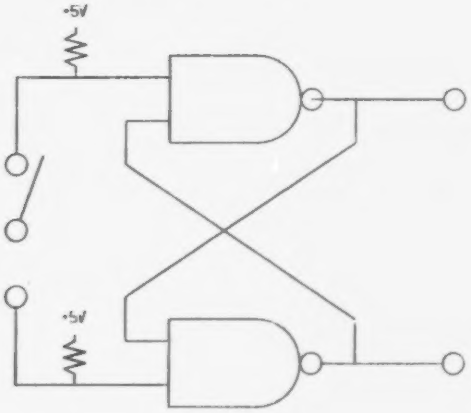
The above solution is a very simple method of switch interfacing when using a small number of switches. There is a problem with this arrangement. The switches are connected directly to the data bus and there is no latching of the data. This requires that the microprocessor wait for a switch to be pressed. When interfacing any switch, the microprocessor must perform many functions. It must address or select the correct switch. It must then detect the switch operation. If required, it may also debounce the switch. After all of these functions have been accomplished, the microprocessor must decode the input and respond accordingly. The following flowchart illustrates the process of debouncing and decoding the switches shown above.


START
SWITCH PUSHED?
NO
YES
WAIT OUT BOUNCE
STILL PRESSED?
NO
YES
READ KEY
ONLY ONE KEY PUSHED?
NO
YES
GET KEY VALUE
EXECUTE PROGRAM

Where many switches are involved, as in a keyboard, it is necessary to scan the key matrix to determine which key has been pressed. Once a key has been depressed, the microprocessor will respond as programmed. Shown below is the schematic diagram of a 16-key switch matrix



Where many keys need to be decoded very rapidly, the microprocessor may not be able to take the time to debounce each switch closure. To compensate, an external means of debouncing switches must be developed. For example, cross-coupled NAND gates can be used to debounce any type of SPDT switch. Schmitt-trigger NAND gates provide the correct logic level for the microprocessor, and the circuit is less susceptible to electrical noise. The figure below illustrates this method of switch debouncing.



While all of the above methods may be used to interface switches to a microprocessor, they are seldom used. The PIA is a much more reliable. With the cost of the PIA now lower than the cost of the tri-state logic used in the other methods, there is no reason not to use the PIA.

ACTIVITY SHEET

F2-13.2

INTERFACING SWITCHES TO THE 6800

1. Define contact bounce, debouncing, decoding, key-matrix.
2. Explain the operation of a program that detects contact closure, provides for debouncing, and decodes a simple keyboard.
3. Construct and test a circuit that detects contact closure, provides for debouncing, and decodes a simple keyboard.

PROGRAM: ELECTRONICS

TASK: SWITCH INTERFACING

TASK #: F2-13.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Prepare software and hardware to perform interface operations with switches.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

SWITCH INTERFACING

F2-13.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required data recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

SWITCH INTERFACING

EXAM F2-13.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on switch interfacing. Each of the statements is true or false. Place the letter associated with the correct choice (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM F2-13.4

1. Contact bounce occurs only when a mechanical switch is being closed.

   A. True
   B. False

2. Decoding a switch means to figure out what sequence of events it is to produce when it is pressed.

   A. True
   B. False

3. To simplify the decoding of a large number of switches, the switches are often arranged in a matrix.

   A. True
   B. False

4. Most microprocessors are unable to decode more than 64 switches.

   A. True
   B. False

5. It is possible to use the microprocessor to cancel the effect of contact bounce.

   A. True
   B. False

6. If a switch is not debounced, the microprocessor may be fast enough to respond to each bounce as if it were a separate switch closure.

   A. True
   B. False

7. It is possible to use cross-coupled NAND gates to debounce a SPST switch.

   A. True
   B. False

8. The switch is the most popular input device used with microprocessors.

   A. True
   B. False

9. It is not necessary to use tri-state buffers when connecting switches to the data bus of a microprocessor.

   A. True
   B. False

10. One way to decode many switches is to use a look-up table containing vectors to the appropriate subroutine.

   A. True
   B. False

EXAM KEY F2-13.4

1. B
2. A
3. A
4. B
5. A
6. A
7. B
8. A
9. B
10. A

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (6800)

F2-14: PERIPHERAL INTERFACE ADAPTER (PIA)

TASK: Prepare software and hardware to operate the PIA in both input and output modes.

PURPOSE: To understand microprocessor operation you must prepare the software and hardware to operate the PIA. This learning guide will explain the terms and processes necessary to prepare the software and hardware to operate the PIA.

OBJECTIVE: Given a written examination, you will be able to identify the information necessary to prepare software and hardware to operate the PIA in both the input and output modes. To master this task you must score at least 80% on the written examinations and laboratory exercises.

ESTIMATED CLASS TIME: 5 HOURS

PERIPHERAL INTERFACE ADAPTER

LEARNING STEPS

F2-14

READ: Information Sheet F2-14.1, "PIA Operation." Material on 6800 PIA operation.

READ: Information on 6800 PIA operation from the following resource list.

COMPLETE: Activity Sheet F2-14.2, "PIA Operation."

REVIEW: Information Sheet F2-14.1, and Activity Sheet F2-14.2.

COMPLETE: Laboratory performance on 6800 PIA operation. Contact your instructor.

COMPLETE: Performance Checklist F2-14.3.

COMPLETE: Written Exam F2-14.4 for mastery of this task.

PERIPHERAL INTERFACE ADAPTER

RESOURCES

F2-14

1. Brunner, INTRODUCTION TO MICROPROCESSORS (Reston, 1982).
2. Gilmore, INTRODUCTION TO MICROPROCESSORS.
3. Motorola, MICROPROCESSOR APPLICATION MANUAL.
4. Heathkit, MICROPROCESSORS.
5. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS.
6. Branko and Sopucek, MICROPROCESSORS AND MICROCOMPUTERS.
7. Goody, THE VERSATILE MICROCOMPUTER (SRA, 1982).
8. Additional references as available.

REQUIRED EQUIPMENT

6800 Microprocessor Trainer
Oscilloscope
DMM

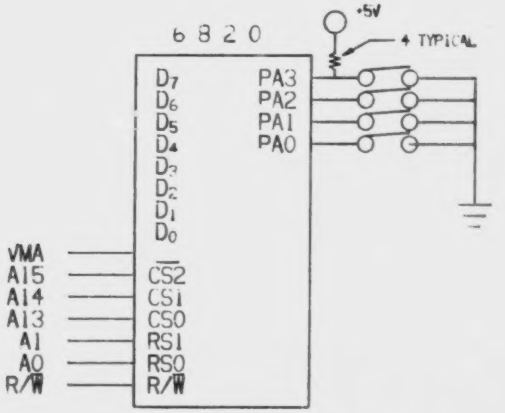
INFORMATION SHEET

F2-14.1

PIA OPERATION

Most microprocessors are accompanied by a group of support chips designed to simplify the interfacing of the microprocessor to the outside world. One of the support chips for the 6800 is the 6820 peripheral interface adapter (PIA). The 6820 can be used with any microprocessor, appearing to the MPU as a series of memory locations.

We have covered the interfacing of input and output devices to the MPU, using tri-state TTL integrated circuits. Remember that it was necessary to buffer and/or latch the data and decode the addressing. The 6820 is capable of doing this and more. The figure shown below illustrates the connections necessary to use the PIA to interface 4 normally open push button switches.



The PIA consists of two basic parts. The first part is the MPU side. This side connects to the address, data, and control lines. The other side of the PIA is the peripheral side. This side connects to the peripheral. There are two groups of data lines, 8-bits each, available on this side of the PIA. There are also two sets of control lines on this side of the PIA.

Besides the hardware advantage the PIA can be configured under software control. The PIA contains two sets of internal registers, one for each half of the peripheral side of the PIA. Each set of three registers contains output, data direction, and control registers. These registers are addressed by the MPU as two locations in memory. It is possible to have three registers located in two memory locations by using a bit of one of the registers to select between two registers located at the other address. Bit 2 of the control register is such a bit, and it selects between the data direction register and the output register.

By writing to bit 2 of the control register, the MPU is capable of selecting either the output register or the data direction register. Each bit of the data direction register corresponds to a respective data line. If a bit is set to a 1, the data line will be configured to function as an output. A zero sets the data line to function as an input. Bit 2 is reset and the MPU can now address the output register. This process is called initializing the PIA. The PIA also has a NOT RESET line. When this line is taken low, the PIA is reset. This sets the PIA data direction register to zeros thus configuring the data lines as inputs.

The following is a program that initializes a PIA located at 8000_{16} as eight input and eight output lines.

INITIALIZATION OF PIA AT $8000

```
   ADDR. OPCODE         MNEMONIC          COMMENTS
1  0000  86    00       LDA A    #00      0 is for inputs
2  0002  B7    8000     STA A    $8000    Write to A-side of PIA
3  0005  86    04       LDA A    #04      Change bit-2 in control reg.
4  0007  B7    8001     STA A    $8001    Write to control register
5  000A  86    FF       LDA A    #$FF     1 is for outputs
6  000C  B7    8002     STA A    $8002    Write to B-side of PIA
7  000F  86    04       LDA A    #04      Change bit-2 in control reg.
8  0011  B7    8003     STA A    $8003    Write to control register
```

The first line of this program loads accumulator A with zeros. These zeros are written to the A-side of the PIA in the second line. This configures side A of the PIA as inputs. The third line of the program loads accumulator A with the value 04_{10}, which is 00000100_2. Notice that bit 2 is set to a 1. This value, when written to the control register, de-selects the data direction register and selects the data register. Line four writes this value to the control register. Now the data register is located at 8000_{16}. Line five reloads the accumulator with the value FF_{16} or 11111111_2. Line six stores the accumulator in memory location 8002_{16}, which represents the data direction register for side B of the PIA. A 1 in each location configures the data line as an output. Line seven loads accumulator A with the value 04_{10}. The eighth and last line changes bit 2 in the control register of side B of the PIA to a 1. This configures memory location 8002_{16} as the data port to side B of the PIA.

It is possible for the PIA to interface to output devices such as LEDs, printers, and other peripherals. The microprocessor controls the movement of data into and out of the PIA. The PIA is capable of waiting for data to appear by constantly reading the data register. This process is known as polling. Another method is to enable the IRQ function on the PIA. Whenever the IRQ line is activated, the processor will respond to the signal and run an interrupt program designed to read or write to the PIA. This method is preferred because it uses much less of the processor's time. The process of using interrupts is more difficult than using polling. The use of interrupts will not be covered in this module.

ACTIVITY SHEET

F2-14.2

PIA OPERATION

1. Explain how to interface a PIA to a 6800 microprocessor.
2. Explain the steps necessary to initialize a PIA.
3. Explain the operation of the PIA.
4. Explain the function of the output, control, and data direction registers in a PIA.
5. Write a program to configure a PIA located at 4000_{16} with side A as outputs and side B as inputs.

PROGRAM: ELECTRONICS

TASK: PERIPHERAL INTERFACE ADAPTER

TASK #: F2-14.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Prepare software and hardware to operate the PIA in both input and output modes.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

PERIPHERAL INTERFACE ADAPTER

F2-14.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required data recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

[illegible] check in the **no** column for a critical item is an automatic fail[illegible]r this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

PERIPHERAL INTERFACE ADAPTER

EXAM F2-14.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on peripheral interface adapter. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Place the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

1748

EXAM F2-14.4

1. The PIA is a device that is used to ____________.

   A. multiplex LED's.
   B. simplify the I/O process.
   C. debounce switches.
   D. interface with a CRT.

2. The PIA is reset by pulling its ______ line low.

   A. reset
   B. VMA
   C. not reset
   D. IRQ

3. The RS1 line of the PIA is normally connected to address line ____ of the microprocessor.

   A. A1
   B. A2
   C. A3
   D. A15

4. When reset, the contents of all PIA registers are reset to ____________.

   A. 00_{16}
   B. $0F_{16}$
   C. $F0_{16}$
   D. FF_{16}

5. The three registers of the PIA are ____________.

   A. accumulator, control, data
   B. data, control, index
   C. MPU, ACIA, VMA
   D. data direction, control, output

6. The A side of a PIA is selected when ____________.

   A. RS0 = 0.
   B. RS0 = 1.
   C. RS1 = 0.
   D. RS1 = 1.

7. A disadvantage of the PIA over conventional combinational logic circuits is that ___________.

   A. more IC's are required.
   B. it is software programmable.
   C. it requires a separate address decoder.
   D. none of the above.

8. When a rest signal is applied to a PIA, ___________.

   A. both sides of the PIA are configured as inputs.
   B. both sides of the PIA are configured as outputs.
   C. both sides of the PIA are tri-stated.
   D. neither side of the PIA is affected.

9. To select the output register, bit __ of the control register must be set to a 1.

   A. 1
   B. 2
   C. 4
   D. 6

10. A PIA has __ chip select lines.

   A. 1
   B. 2
   C. 3
   D. 4

EXAM KEY F2-14.4

1. B
2. C
3. A
4. A
5. D
6. C
7. D
8. A
9. B
10. C

ELECTRONICS

PERFORMING MICROPROCESSING OPERATIONS (6800)

F2-15: USING THE PERIPHERAL INTERFACE ADAPTER

TASK: Prepare software and hardware to interface analog-to-digital and digital-to-analog converters to the 6800.

PURPOSE: To understand microprocessor operations you must prepare the software and hardware to interface the PIA to the outside word. This learning guide will explain the terms and processes necessary to prepare the software and hardware to perform interface operations with the PIA.

OBJECTIVE: Given a written examination, you will be able to identify the information necessary to prepare software and hardware to interface analog-to-digital and digital-to-analog converters to the 6800 microprocessor. To master this task, you must score at least 80% on the written examinations and laboratory exercises.

ESTIMATED CLASS TIME: 5 HOURS

USING THE PERIPHERAL INTERFACE ADAPTER

LEARNING STEPS

F2-15

READ: Information sheet F2-15.1, "PIA Interfacing."

READ: Information on 6800 PIA interfacing in one or more of the references.

COMPLETE: Activity Sheet F2-15.2, "PIA Interfacing."

REVIEW: Information Sheet F2-15.1, and Activity F2-15.2

COMPLETE: Laboratory performance on 6800 PIA interfacing. Contact your instructor.

COMPLETE: Performance checklist F2-15.3. Contact your instructor.

COMPLETE: Written Examination F2-15.4 for mastery of this task.

USING THE PERIPHERAL INTERFACE ADAPTER

RESOURCES

F2-15

1. Brunner, INTRODUCTION TO MICROPROCESSORS (Reston, 1982).
2. Gilmore, INTRODUCTION TO MICROPROCESSORS.
3. Motorola, MICROPROCESSOR APPLICATION MANUAL.
4. Heathkit, MICROPROCESSORS.
5. Hall, MICROPROCESSORS AND DIGITAL SYSTEMS.
6. Branko and Sopucek, MICROPROCESSORS AND MICROCOMPUTERS.
7. Goody, THE VERSATILE MICROCOMPUTER (SRA, 1982).
8. Additional references as available.

REQUIRED EQUIPMENT

680 Microprocessor Trainer
Oscilloscope
DMM

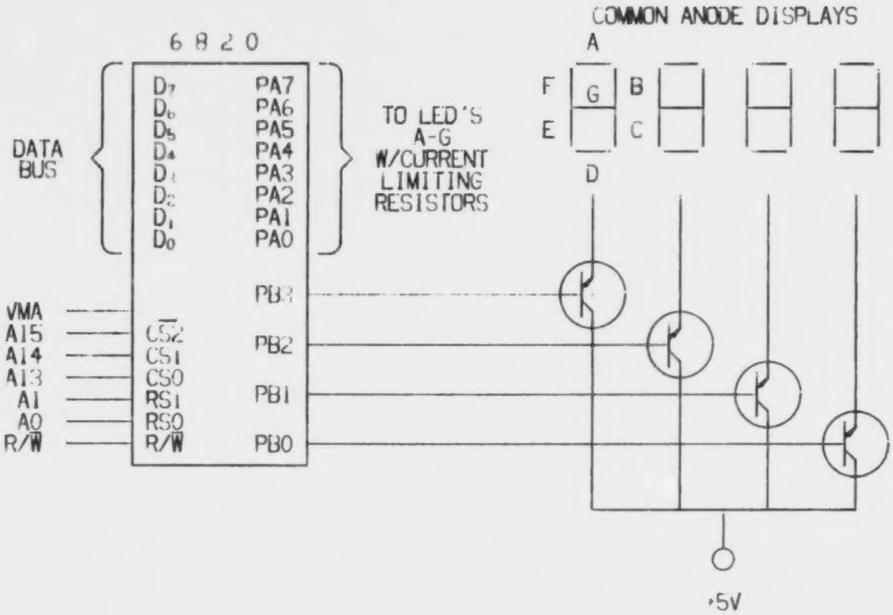
INFORMATION SHEET

F2-15.1

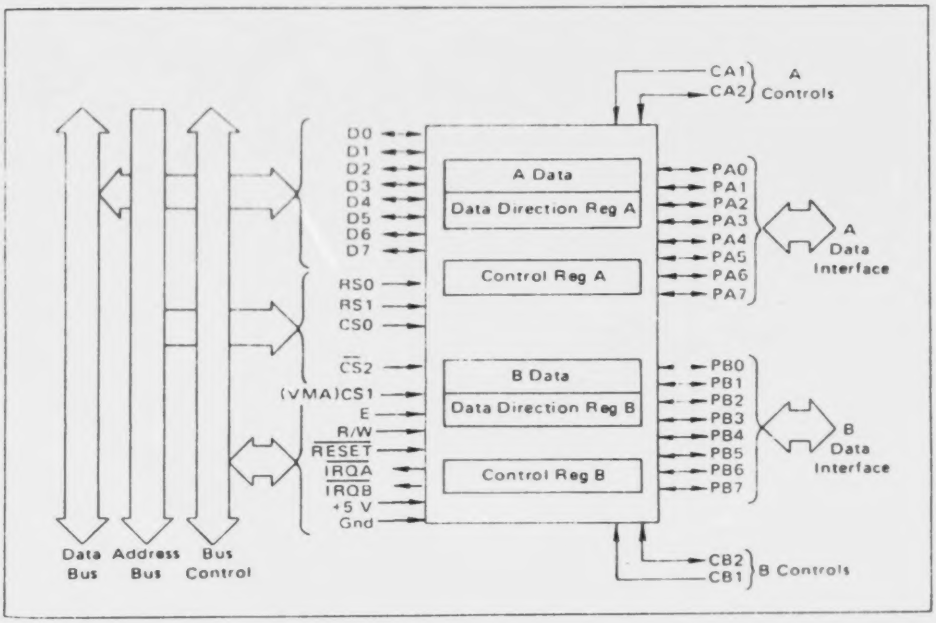
PIA INTERFACING

Once the PIA has been properly installed, it is necessary to connect the PIA to a peripheral device to accomplish a desired task.

One task that a PIA is often called upon to accomplish is the driving of LEDs. Because the power handling capability of the PIA is very low, it is necessary to provide buffer IC's to drive the LEDs. However, these can be simple buffers or latches. It is not necessary to provide decoder/drivers for the displays because it is cheaper and much more flexible to do the decoding in software. The figure below illustrates the connection of PIA to 7-segment displays.


6820
DATA BUS
D_7 D_6 D_5 D_4 D_3 D_2 D_1 D_0
PA7 PA6 PA5 PA4 PA3 PA2 PA1 PA0
TO LED'S A-G W/CURRENT LIMITING RESISTORS
COMMON ANODE DISPLAYS
A B C D E F G
VMA
A15
A14
A13
A1
A0
R/W̄
CS̄2
CS1
CS0
RS1
RS0
R/W̄
PB3
PB2
PB1
PB0
+5V

Another task for the PIA is the decoding of a keyboard. The PIA can be software programmed to provide the necessary sequences to decode the key matrix, debounce the keys, and execute the corresponding program. Once again, because the MPU determines the actual function performed by each key, it is possible to have more than one function on a given key. The shift key on an electronic typewriter is an example of this capability. When it is pushed, each key represents a capital letter instead of a lower case letter. The schematic diagram below is an example of decoding a 16-key matrix.


CA1
CA2
A Controls
D0
D1
D2
D3
D4
D5
D6
D7
A Data
Data Direction Reg A
PA0
PA1
PA2
PA3
PA4
PA5
PA6
PA7
A Data Interface
RS0
RS1
CS0
Control Reg A
$\overline{CS2}$
(VMA)CS1
E
R/W
$\overline{RESET}$
$\overline{IRQA}$
$\overline{IRQB}$
+5 V
Gnd
B Data
Data Direction Reg B
Control Reg B
PB0
PB1
PB2
PB3
PB4
PB5
PB6
PB7
B Data Interface
CB2
CB1
B Controls
Data Bus
Address Bus
Bus Control

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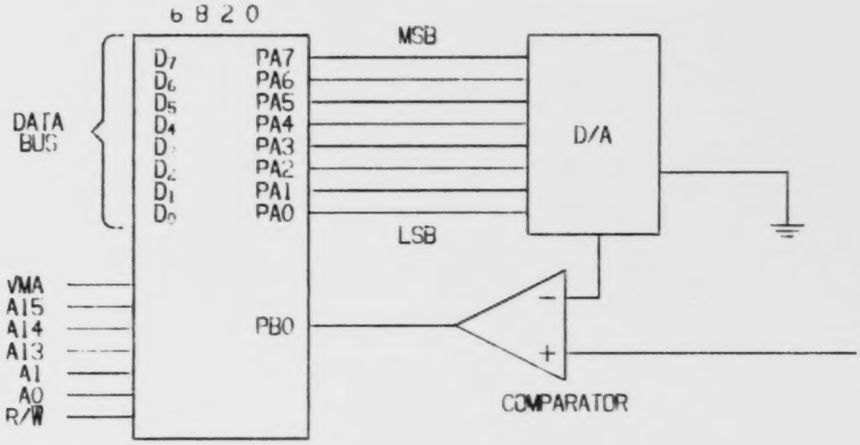
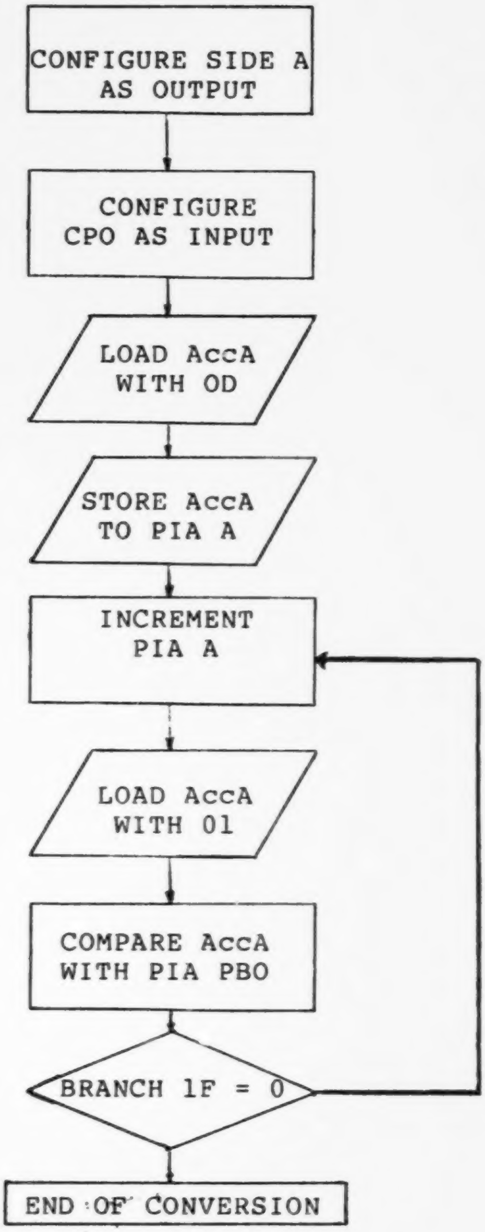
INFORMATION SHEET F2-15.1 CONT'D.

The PIA is capable of performing difficult tasks such as analog-to-digital and digital-to-analog conversions. These functions are required often in commercial and industrial applications. Additional ADCs and DACs ICs are required to perform these functions, but the PIA makes interfacing to these chips much easier.

Some analog-to-digital converters are constructed using digital-to-analog converters. The microprocessor outputs a binary value to the DAC which is connected to one side of a comparator to which the unknown signal has been connected. The microprocessor then looks for a signal from the comparator generated, the MPU through the PIA sends a large number to the ADC and waits for the comparator signal. The process repeats continually until either the comparator signals a match or the microprocessor outputs the largest binary number available. The circuit below illustrates A/D hardware requirements.


6820
DATA BUS
D7
D6
D5
D4
D3
D2
D1
D0
PA7
PA6
PA5
PA4
PA3
PA2
PA1
PA0
MSB
LSB
D/A
VMA
A15
A14
A13
A1
A0
R/W
PB0
-
+
COMPARATOR

The following is a flowchart of a ramping A/D technique. The microprocessor starts by outputting the smallest voltage available. If there is no response from the comparator, the microprocessor increases the output voltage. This process continues as indicated above. One shortcoming of this program is that the time required to convert the voltage is dependent on the magnitude of the voltage. The greater the voltage, the longer the conversion takes to accomplish.


CONFIGURE SIDE A AS OUTPUT
CONFIGURE CPO AS INPUT
LOAD AccA WITH OD
STORE AccA TO PIA A
INCREMENT PIA A
LOAD AccA WITH 01
COMPARE AccA WITH PIA PBO
BRANCH 1F = 0
END OF CONVERSION

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INFORMATION SHEET F2-15.1 CONT'D.

A better way to accomplish this is to use the process of successive approximation. Each power of two, starting with the largest (D7), is output from the microprocessor to the comparator. If the comparator indicates that the voltage is less than the unknown voltage, the bit is set to a one. This process is completed for each of the 8 bits. The binary number that results from the 8-step process is the digital approximation of the analog signal. The more bits used in the A/D converter, the closer the approximation is to the actual value.

ACTIVITY SHEET

F2-15.2

PIA INTERFACING

1. Explain how to interface a digital-to-analog converter to a microprocessor.

2. Explain how a digital-to-analog converter converts digital information into an analog value.

3. Explain the operation of a voltage comparator.

4. Flowchart the process of successive approximation for use with the ramp conversion hardware.

5. Write a successive approximation program using the above flowchart.

6. Construct the circuit and execute the successive approximation program written above.

PROGRAM: ELECTRONICS

TASK: USING THE PERIPHERAL INTERFACE ADAPTER

TASK #: F2-15.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

TERMINAL PERFORMANCE OBJECTIVE:

Prepare software and hardware to interface analog-to-digital and digital-to-analog converters to the 6800.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 6 out of 7 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 6 out of 7 points or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

USING THE PERIPHERAL INTERFACE ADAPTER

F2-15.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	YES	NO	N/A
*1.	Was 100% of program entered?			
*2.	Did program function with 100% accuracy?			
3.	Was required equipment used?			
*4.	Was required data recorded?			
5.	Was equipment used according to specifications?			
*6.	Were all safety precautions followed?			
7.	Was equipment returned to proper storage area?			

Any check in the **no** column for a critical item is an automatic failure for this module.

TOTAL POINTS POSSIBLE ______

POINTS NECESSARY FOR MASTERY ______

STUDENT'S SCORE ______

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USING THE PERIPHERAL INTERFACE ADAPTER

EXAM F2-15.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on using the peripheral interface adapter. Each of the statements is true or false. Place the letter associated with the correct choice (A or B) in the numbered blank space on your answer sheet. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

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EXAM F2-15.4

1. When a PIA is used to debounce keys, input data from the key is inverted before it is accepted.

   A. True
   B. False

2. The purpose of the PIA is to simplify the problem of interfacing the MPU to input/output devices.

   A. True
   B. False

3. The advantage of the PIA over conventional combinational logic is that any data line may be configured as both inputs and outputs at the same time.

   A. True
   B. False

4. When a PIA is used with an analog-to-digital converter, it is necessary always to latch the data from the microprocessor to the converter.

   A. True
   B. False

5. The PIA is capable of being properly used even when it has not been fully decoded.

   A. True
   B. False

6. The control lines on the peripheral side of the PIA can be used only as inputs.

   A. True
   B. False

7. It is a good practice to buffer the data lines to a key matrix when decoding with the PIA.

   A. True
   B. False

8. Because the program slows down the operation of the circuit, it is not possible to use an MPU to multiplex segmented displays.

   A. True
   B. False

9. The PIA can be connected to an audio amplifier system and a speaker and produce musical tones.

   A. True
   B. False

10. Successive approximation is the technique used to assist in the conversion of analog signals to digital signals.

   A. True
   B. False

EXAM KEY F2-15.4

1. B
2. A
3. B
4. B
5. A
6. B
7. A
8. B
9. A
10. A

ELECTRONICS

PERFORMING LAB PRACTICES

G 1: TROUBLESHOOTING

TASK: Diagnose malfunctions applying logical troubleshooting techniques.

PURPOSE: Troubleshooting is another term for finding out why something doesn't work properly. If you follow some logical sequence, you will be able to locate most difficulties occurring in equipment. Many times the trouble will be so complex that it will require many hours of concentration and work. In this learning guide you will be introduced to troubleshooting techniques.

OBJECTIVE: Given access to all necessary tools and equipment, you will diagnose malfunctions by applying logical troubleshooting techniques. To master this task, you must score 80% on a written exam and meet your instructor's standards on a troubleshooting lab.

ESTIMATED CLASS TIME: 3 HOURS

TROUBLESHOOTING

LEARNING STEPS

G 1

READ: Information Sheets G 1.1 on "Troubleshooting."

VIEW: Audio/Visual on Troubleshooting. See instructor.

COMPLETE: Activity Sheet G 1.2 on "Troubleshooting."

COMPLETE: Lab Evaluation G 1.3. See instructor.

TROUBLESHOOTING

RESOURCES

1. The manual that is provided with the defective equipment may include information on troubleshooting.

2. Contact the manufacturer of the defective equipment for more information.

INFORMATION SHEET

G 1.1

TROUBLESHOOTING

Technicians who work with electronic hardware must be able to troubleshoot electronic equipment. The service technician, the production tester, the customer engineer, and the engineering designer all do some troubleshooting as part of their job. A systematic or logical approach can be very effective in locating troublesome areas.

Troubleshooting requires:

1. Knowing how the system works.
2. Knowing how to use test equipment.
3. Knowing how to use technical manuals and references effectively.
4. Being able to find the trouble in any equipment through analysis in logical sequence.
5. Using your physical senses plus common sense!

The whole idea of troubleshooting breaks down to common sense. The first step is to always open the equipment up and perform a visual inspection. If everything looks OK, then begin the circuit or system checkout. Review the manuals for the equipment being tested and follow the troubleshooting tables. No one knows the equipment better than the manufacturer.

After the source of trouble has been located, the faulty part or parts should be replaced if possible. If there is no part available, the device should be returned to temporary service by improvising, if at all possible. Do not, however, try to fix something that is impossible to fix, or try to "hay wire" it if it won't last until the new part is received.

GENERAL INSPECTION

General inspection is nothing more than looking for the obvious. Upon receiving a piece of equipment for repair, you should do several things before getting into actual circuit or system checkout. In the initial inspection of any equipment, the first thing to do is open up the equipment for a look.

1. Burned resistors are often quite obvious; they may be charred, blistered or bulged out, have discolored color bands, and even holes in them.

2. Broken parts are another source of trouble; these may come in the form of cracks, leads pulled out of parts, or completely demolished parts.

3. Broken wires and poor connections come from vibration or poor construction. Some equipment has even come from the factory with wires missing in rather obvious places.

4. Smoke may be coming from parts when equipment is turned on, or it may be shorted internally.

5. Heat damage or hot parts may be an indication of several things: dry bearings, too much voltage, too much current, and so on.

6. Oil leaks and water leaks may be hard to find, but some are easily spotted by puddles underneath them. Some electrical parts may be leaking fluid or wax and should be replaced.

7. Loose, damaged or worn parts can be noticed by visual and touch examination. Loose parts, damaged surfaces due to rubbing, and worn belts are examples of troubles encountered.

8. Noisy parts that squeak when operating, or vibrate violently or run rough and drag are often sources of problems in electrical, mechanical and electronic troubleshooting.

If you suspect that a part is bad, turn the equipment off and smell it, touch it, and examine it. A transformer that is good does not smell, but a burned transformer will have a definite odor. A power resistor is designed to get hot, but a small half watt resistor should not burn your finger when touched. You may notice a crack in a water pump, while close up, that you might not have noticed if standing three feet away. The important thing to remember is to give the device an examination before trying to find hidden problems.

Before proceeding further, it is best to take a few moments to clean the equipment to make it easier to check further. Be careful not to turn any adjusting screws while cleaning.

Never should you attempt repairs until you have read the applicable technical manual, making note of possible circuit misalignment or the need for recalibration resulting from parts replacement. In the corrective maintenance section of equipment instruction manuals, troubleshooting charts are often provided for the localization of trouble. When these charts are supplied, they should be utilized for the correction of any trouble.

TROUBLESHOOTING

There are several methods practiced in troubleshooting electronic equipment.

VISUAL INSPECTION

Visual inspections should be made of the following:

1. power supply and fuses
2. seating of tubes in their sockets
3. input and output connections
4. positions of switches and panel controls
5. all parts for evidence of burning or charring
6. variable capacitors for shorted plates.

Load resistance testing, shock testing, and tube testing are all methods used in servicing vacuum tube equipment. Even though much of the equipment today is built of semiconductors, equipment incorporating tubes are still in service.

POINT-POINT ANALYSIS

This method calls for you to compare a few strategically chosen (from experience) voltage or resistance readings with those indicated in the charts, thus enabling you to locate the trouble quickly. The less experienced technician obtains the same end result, although he/she may have to take many more tedious and time-consuming readings.

SIGNAL TRACING

On certain equipment, an effective stage-by-stage test can be made by signal tracing. The principle is to localize the trouble by permitting a signal of the correct frequency to be passed through an individual stage while the output is observed. If there is no output (or, as is usually the case, the output is extremely low), it follows that the stage must be defective. One method, sometimes called sensitivity testing, is to feed a signal of the correct frequency into the input of a stage, and measure the output, or amplification, by means of an electronic voltmeter or dynamic analyzer. When the faulty stage is found, point-to-point analysis (either voltage or resistance) is then used to locate the defective part or component.

When the equipment is both electrical and mechanical in nature, see if the motor turns freely with the belts off. If the equipment has belts, check to see if they are glazed, frayed or cut. Feel the bearings and motors to find if they are overheating. Check wire connections and terminals. Listen for noise in gear boxes and so on.

REPAIR OF EQUIPMENT

After the nature of the problem has been determined, the next step is to repair the equipment. You should be able to get several types of information from the faulty equipment or the operation manual: the brand name, model number, serial number, part number or part name. All of this information is necessary in ordering the right part.

If it is at all possible, you should try to improvise a temporary solution so the customer can use the equipment while the parts are being ordered. In some cases this is not possible, but if the part is a timer in a washer, for example, it may be possible to do temporary repairs so it will work until the new part comes. Always advise the customer that the repair is temporary.

There are various techniques to troubleshooting different circuits. As your troubleshooting ability grows, you can develop your own systematic approach to solving a problem. There is no one right way of troubleshooting, but the common sense approach should be included in any problem-solving method.

ACTIVITY SHEET

G 1.2

TROUBLESHOOTING

Complete the following:

1. List 5 requirements necessary to be able to troubleshoot.

2. When beginning troubleshooting a piece of defective equipment, what should be done first?

3. Name 4 senses that the troubleshooting procedures are based upon.

4. Many times general inspection of equipment or devices that have failed will reveal a problem. List eight things you should look for in a general inspection.

5. Can all equipment failures be solved? Explain.

6. List 5 visual inspections that should be made.

ACTIVITY SHEET G 1.2 CONT'D.

7. What is point-to-point analysis?

8. What is signal tracing?

9. When beginning to check for hidden or specific troubles, what should you do?

ACTIVITY SHEET G 1.2

ANSWER KEY

1.
   - -Using your physical senses plus common sense!
   - -Knowing how the system works
   - -Knowing how to use test equipment
   - -Knowing how to use technical manuals and references effectively
   - -Being able to find the trouble in any equipment through analysis in logical sequence

2. Open the equipment up and perform a visual inspection.

3. In every case, use your senses of sight, touch, smell, and hearing. It is on these senses that the troubleshooting procedures are based.

4. There are several things for which you should be looking.

   a. Burned resistors are often quite obvious; they may be charred, blistered, or bulged out, have discolored color bands, and even holes in them.

   b. Broken parts are another source of trouble; these may come in the form of cracks, leads pulled out of parts or completely demolished parts.

   c. Broken wires and poor connections come from vibration or poor construction. Some equipment has even come from the factory with wires missing in rather obvious places.

   d. Smoke may be coming from parts when equipment is turned on, or it may be shorted internally.

   e. Heat damage or hot parts may be an indication of several things; dry bearings, too much voltage, too much current, and so on.

   f. Oil leaks and water leaks may be hard to find, but some are easily spotted by puddles underneath them. Some electrical parts may be leaking fluid or wax and should be replaced.

   g. Loose, damaged or worn parts can be noticed by visual and touch examination. Loose parts, damaged surfaces due to rubbing, and worn belts are examples of troubles encountered.

ACTIVITY SHEET G 1.2 ANSWER KEY CONT'D.

h. Noisy parts that squeak when operating, or vibrate violently, or run rough and drag are often sources of problems in electrical, mechanical and electronic troubleshooting.

5. You are limited to some extent in the repairs that you are able to perform on some equipment (and still have it function accurately and reliably), principally because you do not have the tools and equipment, and sometimes the spare parts, necessary for this specialized form of maintenance.

6. Visual inspections should be made of the following:
   a. power supply and fuses
   b. seating of tubes in their sockets
   c. input and output connections
   d. positions of switches and panel controls
   e. all parts for evidence of burning or charring
   f. variable capacitors for shorted plates

7. Most equipment is supplied with sufficient information to permit you to compare a few strategically chosen (from experience) voltage or resistance readings with those indicated in the charts, and to locate the trouble quickly.

8. The principle is to localize the trouble by permitting a signal of the correct frequency to be passed through an individual stage while the output is observed.

9. There are some things necessary to check when beginning to examine equipment for hidden or specific troubles. The most important thing is to start with the most common or broadest area and narrow it down to specific parts.

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TROUBLESHOOTING

EVALUATION

G 1.3

1. Given a piece of faulty or defective electronic equipment, troubleshoot and repair it. You will be evaluated by your instructor. See your instructor.

EVALUATION ANSWER

G 1.3

1. If the student follows the proper procedures, uses the proper techniques to troubleshoot the defective equipment, and follows all guidelines - the student should be evaluated as "acceptable." (Emphasis should be placed on technique.)

ELECTRONICS

PERFORMING LAB PRACTICES

G 2: PREPARE AND USE SERVICE RECORDS OR DOCUMENTATIONS

TASK: Prepare and use service records or documentations.

PURPOSE: Service records are used to document maintenance on electronic equipment. The technician keeps a record on every item that crosses the bench. In this learning guide you will learn how to complete service records and/or documentation of maintenance.

OBJECTIVE: Given access to all necessary reference material, you will prepare and use service records or documentation. To master this task you must successfully meet the instructor's standard for completing a service record.

ESTIMATED CLASS TIME: 3 HOURS

SERVICE RECORDS

LEARNING STEPS

G 2

READ:	Information Sheet G 2.1, "Service Records."
COMPLETE:	Activity Sheet G 2.2 on "Service Records."
REVIEW:	All material covered in this learning guide.
COMPLETE:	Evaluation G 2.3. See instructor.

INFORMATION SHEET

G 2.1

SERVICE RECORDS

To organize your repair work, keep a service record. A service order form, for example, can 1) give the technician a history of service performed on any piece of equipment, 2) give the customer proof of work performed, and 3) create a permanent record for accounting purposes.

Because every business is different, there is really no such thing as a standardized service order form. Each business tailors a service record form to suit its own needs.

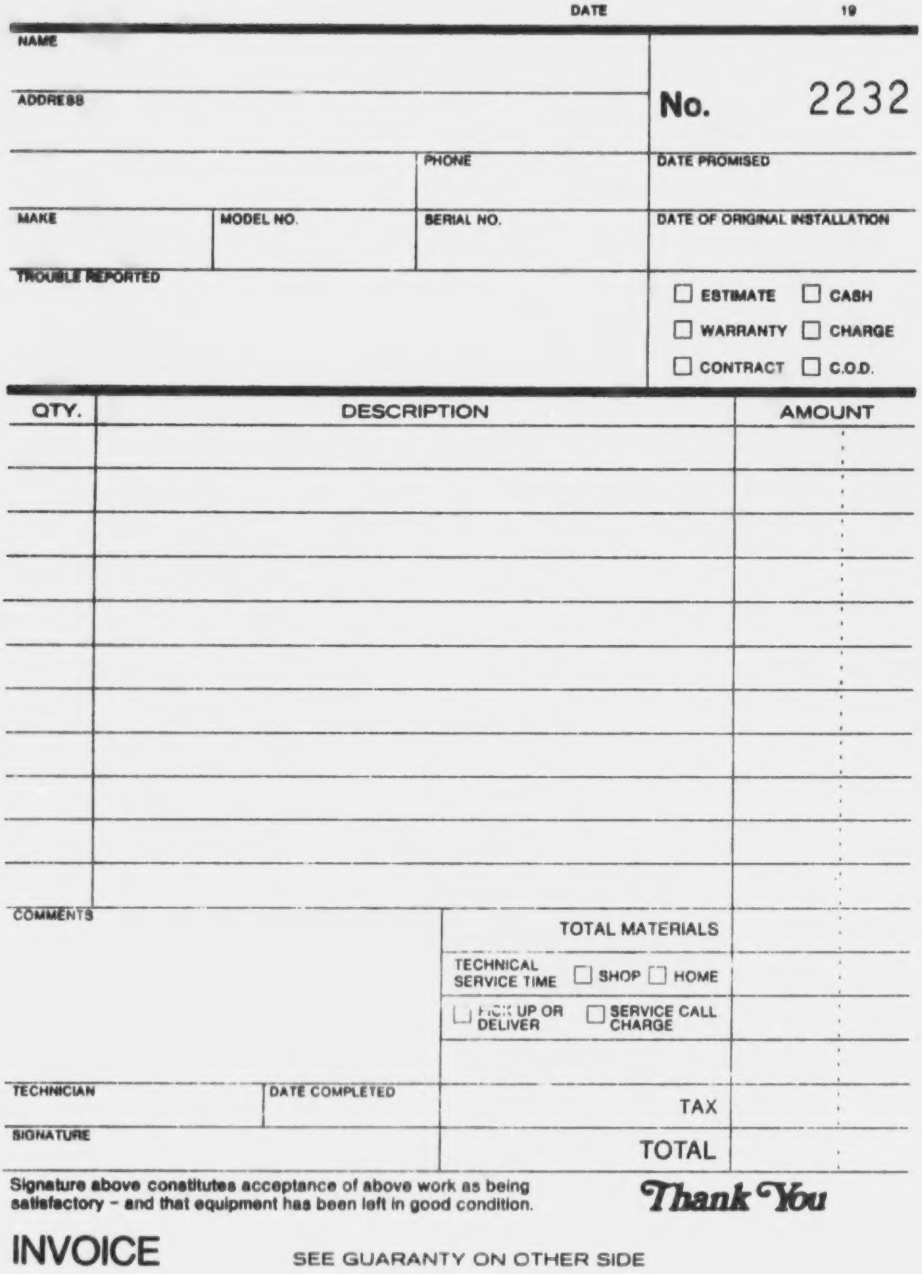
Most service record forms require 1) customer information, 2) model or serial numbers of the equipment, 3) description and quantity of parts replaced, 4) cost to customer, 5) technician's comments and signature, 6) trouble reported and found, and 7) an authorization of the customer.

Documentation of service may range from using a very comprehensive order form to simply writing down information in a ledger. But, in all cases, service records are a way to keep a file on each individual piece of repair work that crosses the bench. To give the customer "proof of services rendered," many service order forms are filled out in duplicate by using carbon paper.

Refer to Figure G 2.1-1 to see one example of a service order form that would be filled out in triplicate.

INFORMATION SHEET G 2.1 CONT'D.

ELECTRONICS, INC.
ANYTOWN, ILLINOIS 00000
(100) 555-5555



DATE 19

NAME

ADDRESS

No. 2232

PHONE

DATE PROMISED

MAKE

MODEL NO.

SERIAL NO.

DATE OF ORIGINAL INSTALLATION

TROUBLE REPORTED

☐ ESTIMATE ☐ CASH
☐ WARRANTY ☐ CHARGE
☐ CONTRACT ☐ C.O.D.

QTY.	DESCRIPTION	AMOUNT

COMMENTS

TOTAL MATERIALS

TECHNICAL SERVICE TIME ☐ SHOP ☐ HOME

☐ PICK UP OR DELIVER ☐ SERVICE CALL CHARGE

TECHNICIAN

DATE COMPLETED

TAX

SIGNATURE

TOTAL

Signature above constitutes acceptance of above work as being satisfactory – and that equipment has been left in good condition.

Thank You

INVOICE

SEE GUARANTY ON OTHER SIDE

FIGURE G 2.1-1

INFORMATION SHEET G 2.1 CONT'D.

Most service forms will have the name of the business that is doing the repair work. Also, personal information about the customer is needed (i.e. name, address, telephone, etc.).

The date is usually noted, along with the model number, serial number and trouble reported. A list of parts needed to repair the equipment and the cost are recorded.

A total of all materials used is entered, and usually other costs are added (i.e. technician time, service call, estimates, etc.). Tax sometimes is included in a service bill, depending on the organization, and a total cost to the customer can be tallied.

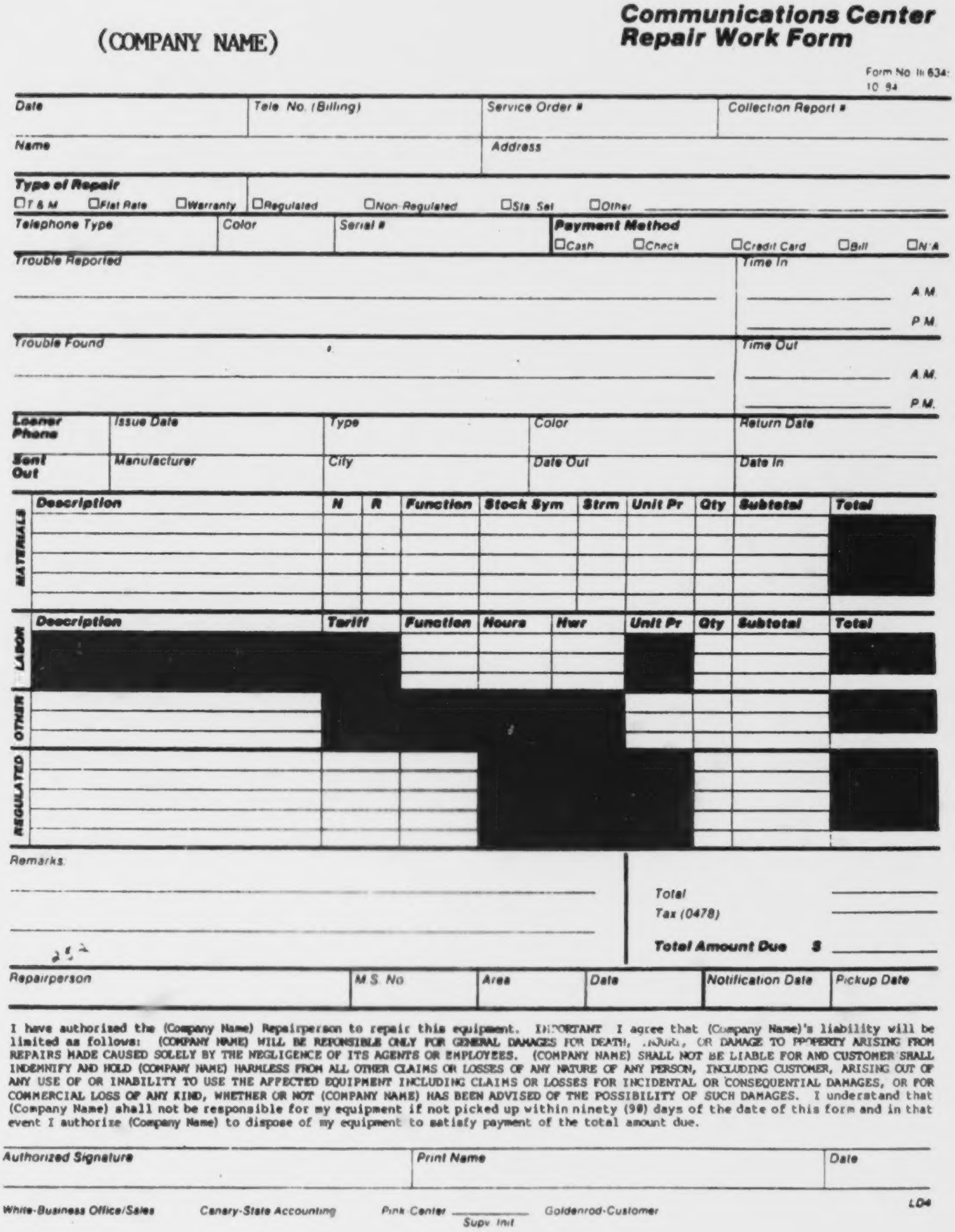
The technician usually notes specific changes made in the equipment and signs the form. The customer must sign the service order form.

Many times an identification tag accompanies the repair work, and the customer must show a claim check to pick up the item from the shop.

There can be literally thousands of service order forms on file; therefore, each form is numbered. After a designated time, due to lack of filing space, a business may destroy old records to make room for future ones. This usually takes place anywhere after 3-5 years. Some service orders can be "saved" for a longer period of time by using a computer.

Another example of a service or repair work form is given in Figure G 2.1-2.

INFORMATION SHEET G 2.1 CONT'D.



(COMPANY NAME)

Communications Center Repair Work Form

Form No III 634:
10 94

Date	Tele No. (Billing)	Service Order #	Collection Report #
Name		Address	

Type of Repair
☐T & M ☐Flat Rate ☐Warranty ☐Regulated ☐Non Regulated ☐Sta Set ☐Other ____________

Telephone Type	Color	Serial #	**Payment Method** ☐Cash ☐Check ☐Credit Card ☐Bill ☐N/A

Trouble Reported	Time In ________ A.M. ________ P.M.
Trouble Found	Time Out ________ A.M. ________ P.M.

Loaner Phone	Issue Date	Type	Color	Return Date
Sent Out	Manufacturer	City	Date Out	Date In

	Description	**N**	**R**	**Function**	**Stock Sym**	**Strm**	**Unit Pr**	**Qty**	**Subtotal**	**Total**
MATERIALS										

	Description	**Tariff**	**Function**	**Hours**	**Hwr**	**Unit Pr**	**Qty**	**Subtotal**	**Total**
LABOR									
OTHER									
REGULATED									

Remarks: ____________

252

Total ________
Tax (0478) ________
Total Amount Due $ ________

Repairperson	M.S. No	Area	Date	Notification Date	Pickup Date

I have authorized the (Company Name) Repairperson to repair this equipment. IMPORTANT I agree that (Company Name)'s liability will be limited as follows: (COMPANY NAME) WILL BE REPONSIBLE ONLY FOR GENERAL DAMAGES FOR DEATH, INJURY, OR DAMAGE TO PROPERTY ARISING FROM REPAIRS MADE CAUSED SOLELY BY THE NEGLIGENCE OF ITS AGENTS OR EMPLOYEES. (COMPANY NAME) SHALL NOT BE LIABLE FOR AND CUSTOMER SHALL INDEMNIFY AND HOLD (COMPANY NAME) HARMLESS FROM ALL OTHER CLAIMS OR LOSSES OF ANY NATURE OF ANY PERSON, INCLUDING CUSTOMER, ARISING OUT OF ANY USE OF OR INABILITY TO USE THE AFFECTED EQUIPMENT INCLUDING CLAIMS OR LOSSES FOR INCIDENTAL OR CONSEQUENTIAL DAMAGES, OR FOR COMMERCIAL LOSS OF ANY KIND, WHETHER OR NOT (COMPANY NAME) HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. I understand that (Company Name) shall not be responsible for my equipment if not picked up within ninety (90) days of the date of this form and in that event I authorize (Company Name) to dispose of my equipment to satisfy payment of the total amount due.

Authorized Signature	Print Name	Date

White-Business Office/Sales   Canery-State Accounting   Pink Center ________ Supv Init   Goldenrod-Customer

LD4

FIGURE G 2.1-2

ACTIVITY SHEET

G 2.2

SERVICE RECORDS

Complete the following:

You have just opened a new business in town. It is an electronic equipment repair shop. To have a permanent record of work completed, you need a service order form designed to suit your needs. Using the information in G 2.1, design a service order form for your business.

ACTIVITY SHEET G 2.2

ANSWER SHEET

Each service order form may vary, but all forms should include most of the information presented in Information Sheet G 2.1. Also, the service order forms may include any pertinent information that may be required for a specific business. Your instructor will grade your form "acceptable" or "not acceptable."

PREPARE AND USE SERVICE RECORDS

EVALUATION

G 2.3

The student must successfully complete a service order form on a piece of electronic equipment that needs repair in the lab and/or has been brought in from outside the lab to be fixed.

PREPARE AND USE SERVICE RECORDS

EVALUATION ANSWER

G 2.3

The service order form must be judged "acceptable" by your instructor.

ELECTRONICS

PERFORMING LAB PRACTICES

G 3: READ AND CONVERT MEASUREMENTS

TASK:	Read and convert measurements.
PURPOSE:	Electronics involves many different units of measurement. In this learning guide you will be able to read and convert measurements.
OBJECTIVE:	Given access to all necessary tools and equipment, you will read and convert measurements. To master this task, you must score 80% on a written criterion exam and performance checklist.

ESTIMATED CLASS TIME: 3 HOURS

READ AND CONVERT MEASUREMENTS

LEARNING STEPS

G 3

READ: Information Sheet G 3.1, "Measurement Conversions."

READ: Information on measurement conversions in one or more resources listed below. See your instructor.

VIEW: Audio/Visual material on "Measurement Conversions." Contact your instructor.

COMPLETE: Activity Sheet G 3.2 on "Measurement Conversions."

COMPLETE: Lab performance on "Measurement Conversions." Contact your instructor for this lab.

REVIEW: All material covered in this learning guide and information presented by your instructor.

COMPLETE: Written Exam G 3.3. Contact your instructor.

READ AND CONVERT MEASUREMENTS

RESOURCES

G 3

1. Oliva and Dale, DC CIRCUITS-VOL. 1 BASIC ELECTRICITY AND CIRCUIT CONCEPTS (Texas Instrument Learning Center, 1979), Fourth Edition.
2. Heathkit Educational Systems, DC ELECTRONICS (1984).
3. Grob, BASIC ELECTRONICS (McGraw-Hill, 1984).
4. Bell and Howell Schools, INTRODUCTION TO ELECTRICITY AND ELECTRONICS (DeVry Institute of Technology, 1984).
5. INTRODUCTION TO INDUSTRIAL ELECTRICITY-ELECTRONICS (Oklahoma Trade and Industrial Education).
6. ELECTROCHEMICAL ACTION AND D-C, (TPC Training Systems, 1984).
7. Generally, most Electronics textbooks.

INFORMATION SHEET

G 3.1

MEASUREMENT CONVERSIONS

A measurement can usually be defined by the units that follow that measurement. Values of power, voltage, current, resistance, conductance, capacitance, inductance or any other electronic variable must be expressed by some unit to determine "how much" is available to the user.

Almost all values can be expressed in scientific notation that use metric prefixes. Prefixes such as milli, kilo, micro, and mega are examples of some of the most common variations of standard units.

At times it is important to know how to convert one value to another larger or smaller unit. As an example, it is a common practice to convert a value such as .0052 amperes to a whole number that is easier to read, such as 5.2 mA. The value .0052A or 5.2 mA represents the same quantity but is expressed in different units.

Another conversion example is .333 MΩ, which can be rewritten to read 333 kΩ. The latter expression is easier to understand because it is a whole number.

To change 600,000 volts to a shorter form, divide by 1000 to equal 600kv. The quantities are the same.

To understand the many prefixes available, and how each value can be expressed by scientific notation, study the following tables.

Powers of Ten

Number	Power of 10	Pronunciation
1 000 000	10^{6}	ten to the sixth power
100 000	10^{5}	ten to the fifth power
10 000	10^{4}	ten to the fourth power
1 000	10^{3}	ten to the third power (ten cubed)
100	10^{2}	ten to the second power (ten squared)
10	10^{1}	ten to the first power (ten)
1	10^{0}	ten to the zero power (one)
0.1	10^{-1}	ten to the minus first power (ten to the minus one)
0.01	10^{-2}	ten to the minus two
0.001	10^{-3}	ten to the minus three
0.0001	10^{-4}	ten to the minus four
0.000 01	10^{-5}	ten to the minus five
0.000 001	10^{-6}	ten to the minus six

Preferred Powers of Ten and Prefixes

Power of ten	Number	Prefix	Abbreviation
10^{-18}	0.000 000 000 000 000 001	atto	a
10^{-15}	0.000 000 000 000 001	femto	f
10^{-12}	0.000 000 000 001	pico	p
10^{-9}	0.000 000 001	nano	n
10^{-6}	0.000 001	micro	μ
10^{-3}	0.001	milli	m
10^{0}	1.000		
10^{3}	1 000	kilo	k
10^{6}	1 000 000	mega	M
10^{9}	1 000 000 000	giga	G
10^{12}	1 000 000 000 000	tera	T

Other Common Prefixes

Power of ten	Number	Prefix	Abbreviation
10^{2}	100	hecto	h
10^{1}	10	deca or deka	da or dk
10^{-1}	0.1	deci	d
10^{-2}	0.01	centi	c

Pronouncing the Prefixes

Always put the main stress on the first syllable of the prefix when pronouncing the SI metric units. Examples are:

kilometer	kil' - o - meter
picofarad	pi' - co - farad
micrometer	mi' - cro - meter

The micrometer measuring device, however, is pronounced mi - crom' - e - ter.

Figure G 3.1-1

INFORMATION SHEET G 3.1 CONT'D.

Derived SI Units

Quantity		Unit		
Name	**Symbol**	**Name**	**Symbol**	**Dimensions**
Area	A			m_2
Volume	V			m^3
Density	ρ			kg/m^3
Velocity	v			m/s
Acceleration	a			m/s^2
Angular velocity	ω			rad/s
Angular acceleration	$\dot{\omega}$			rad/s^2
Frequency	f	hertz	Hz	1/s
Kinematic viscosity				m^2/s
Dynamic viscosity				Pa•s
Volume flowrate				m^3/s
Mass flowrate				kg/s
Energy (work, heat quantity)	W	joule	J	$kg•m^2/s^2$ = N•m
Force	F	newton	N	$kg•m/s^2$ = J/m
Pressure	p	pascal	Pa	N/m^2
Power	P	watt	W	$kg•m^2/s^3$ = J/s
Electric charge	Q	coulomb	C	A•s
Electric potential difference, voltage	V	volt	V	$kg•m^2/s^3•A$ = J/A•s = W/A
Impedance	Z	ohm	Ω	$kg•m^2/s^3•A^2$ = V/A
Reactance	X	ohm	Ω	V/A
Resistance	R	ohm	Ω	V/A
Resistivity	ρ			Ω/m
Admittance	A	siemen	S	A/V
Susceptance	B	siemen	S	A/V
Conductance	G	siemen	S	A/V
Conductivity	σ			S/m = A/V•m
Capacitance	C	farad	F	A•s/V
Inductance	L	henry	H	V•s/A
Electromotive force	$\mathcal{E}$	volt	V	W/A
Electric field strength	E			V/m
Electric displacement	D			C/m
Permittivity	ϵ			F/m
Permittivity (vacuum)	ϵ_o			F/m
Relative permittivity	ϵ_r			
Electric susceptibility	k_e			
Magnetomotive force	F			A
Magnetic field strength	H			A/m
Magnetic flux density	B			Wb/m^2
Magnetic flux	Φ	weber	Wb	V•s

Figure G 3.1-2

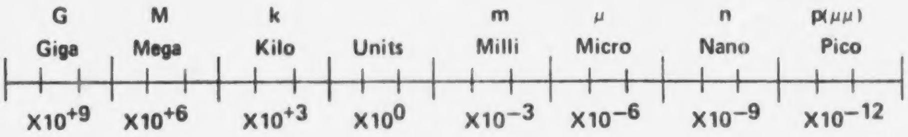
INFORMATION SHEET G 3.1 CONT'D.

Quantity		Unit		
Name	**Symbol**	**Name**	**Symbol**	**Dimensions**
Permeability	μ			H/m
Permeability (vacuum)	μ_o			H/m
Relative permeability	μ_r			
Magnetic susceptibility	κ_m			
Reluctance				A/Wb
Permeance				Wb/A
Specific heat (heat capacity)				J/kg•K
Thermal conductivity				W/m•K
Heat flux (intensity)				J/m^2
Thermal conductance				W/m^2•K
Heat content				J/kg
Heat flux rate (power rate)				W/m^2
Thermal diffusivity				m^2/s
Thermal resistance				K•m^2/W
Customary temperature		degree Celsius	°C	°C = K—273.15
Luminous flux		lumen	lm	cd•sr
Illumination		lux	lx	cd•sr/m^2 = lm/m^2
Luminance				cd/m^2

Figure G 3.1-3

INFORMATION SHEET G 3.1 CONT'D.

SCIENTIFIC NOTATION AND THE METRIC PREFIXES



G
Giga
M
Mega
k
Kilo
Units
m
Milli
μ
Micro
n
Nano
p(μμ)
Pico
X10+9
X10+6
X10+3
X100
X10−3
X10−6
X10−9
X10−12

1 unit = 1 .

. 0 0 1 = 1 milli

1 kilo = 1 0 0 0 .

. 0 0 0 0 0 1 = 1 micro

1 mega = 1 0 0 0 0 0 0 .

. 0 0 0 0 0 0 0 0 1 = 1 nano

1 giga = 1 0 0 0 0 0 0 0 0 0 .

. 0 0 0 0 0 0 0 0 0 0 0 1 = 1 pico

STANDARD FORM: X.XX × $10^{+\text{exponent}}$

Symbol	Prefix	Value	Power of 10
G	giga	1, 0 0 0, 0 0 0, 0 0 0.	$\times 10^{+9}$
M	mega	1, 0 0 0, 0 0 0.	$\times 10^{+6}$
k	kilo	1, 0 0 0.	$\times 10^{+3}$
–	(units)	1 .	$\times 10^{0}$
m	milli	.0 0 1	$\times 10^{-3}$
μ	micro	.0 0 0 0 0 1	$\times 10^{-6}$
n	nano	.0 0 0 0 0 0 0 0 1	$\times 10^{-9}$
p (μμ)	pico	.0 0 0 0 0 0 0 0 0 0 0 1	$\times 10^{-12}$

Figure G 3.1-4

ACTIVITY SHEET

G 3.2

MEASUREMENT CONVERSIONS

Convert all expressions:

1. .450 A = _____mA = _____ μA
2. 6700 = _____kΩ
3. 32751 mA = _____A
4. .325V = _____mV = _____ μV
5. .274 mA = _____ μA
6. .789 μF = _____pF
7. 68000W = _____kW
8. 25,000 Ω = _____kΩ
9. .169H = _____mH
10. 10725 kΩ = _____MΩ

ACTIVITY SHEET G 3.2

ANSWER SHEET

1. 450mA = 450,000 μA
2. 6.7 kΩ
3. 32.751A
4. 325mV = 325,000 μV
5. 274 μA
6. 789,000 pF
7. 68 KW
8. 25 KΩ
9. 169 mH
10. 10.725 MΩ

EXAM G 3.3

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on measurement conversions. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Shade in the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on the ANSWER SHEET, using a #2 pencil to mark your answers. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM G 3.3 CONT'D.

1. The units for current are measured in ______.

A. volts
B. amps
C. ohms
D. mhos

2. Convert .052A to _________mA.

A. 5.2
B. 50.2
C. 52.0
D. 52000

3. 1600 V = _____ KV.

A. 1.6
B. 16
C. 160
D. 160,000

4. "Kilo" stands for ________.

A. 1/1000
B. 1/100,000
C. 100,000
D. 1000

5. 2.67 MΩ = _________ kΩ .

A. .0267
B. .267
C. 2,670
D. 2,670,000

6. The prefix "pico" can be expressed as 1 x 10 units.

A. true
B. false

7. .323 mA = _____ μA.

A. 3.23
B. 323
C. 3230
D. no answer given

EXAM G 3.3 CONT'D.

8. 25mA = .25A.

   A. True
   B. False

9. 7.2 MΩ is equal to _____ Ω .

   A. 720,000
   B. 7,200,000
   C. 7,200
   D. 72,000

10. One milliampere is the same as _____A.

   A. 1
   B. .01
   C. 1,000
   D. .0001

EXAM KEY G 3.3

1. B
2. C
3. A
4. D
5. C
6. B
7. B
8. B
9. B
10. C

ELECTRONICS

PERFORMING LAB PRACTICES

G 4: SET UP AND OPERATE COUNTERS AND GENERATORS

TASK:	Set up and operate frequency counters and signal generators for AC circuits.
PURPOSE:	There will be many times when a circuit will require a signal on its input to be used to check the circuit's operation. These signals are usually obtained from pieces of test equipment called signal generators. Also, circuits which generate their own frequency require that their frequency rate (oscillation) be checked. This task is covered by using a piece of test equipment called a frequency counter. After completing this learning guide, you should be able to operate both pieces of this equipment.
OBJECTIVE:	Given all necessary equipment, you will set up and operate frequency counters and signal generators for AC circuits. To master this task, you must score 80% on a performance checklist.

ESTIMATED CLASS TIME: 3 HOURS

COUNTERS AND GENERATORS

LEARNING STEPS

G 4

READ: Information Sheet G 4.1 on "Counters and Generators."

READ: Information on counters and generators in one or more of the resources listed below.

COMPLETE: Activity Sheet G 4.2 on "Counters and Generators."

COMPLETE: Lab performances on "Counters and Generators." Contact your instructor.

COMPLETE: A review of all the material you have studied on counters and generators.

COMPLETE: Performance Checklist G 4.3 on "Counters and Generators." Contact your instructor.

SET UP AND OPERATE COUNTERS AND GENERATORS

RESOURCES

G 4

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1984). Fifth Edition.
2. Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). Fifth Edition.
3. Badrkhan and Larky, ELECTRONICS: PRINCIPLES AND APPLICATIONS, (South-Western Publishing Company, 1984).
4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS, (McGraw-Hill, 1984). Second Edition.
5. AC ELECTRONICS, (Heath Company, 1982). Nineteenth Printing.
6. OPERATION AND INSTRUCTION MANUALS for the Counters and Generators in your lab.

INFORMATION SHEET

G 4.1

COUNTERS AND GENERATORS

Frequency counters and frequency meters are often mistaken for one another. A "frequency meter" is a special purpose meter which is used to count or measure only the frequency of a waveform. A "frequency counter" is an electronic device which will measure the frequency of a waveform, the period of a waveform, and also events.

Most basic frequency counters consist of five sections: decade counting and display circuits, which count the frequency and displays it on a multi-digit display; the time-base oscillator, which is used as an internal reference for the unknown frequency; the divider chain, which divides or steps down the time-base frequency to a variety of different time references; gate and control circuits, which are used to gate the unknown frequency for a known period of time so that it can be counted by the decade counting section. The control portion provides latching and clearing of the counters and displays. The last section provides amplification and wave-shaping for the incoming signal.

The complexity of a "frequency counter" will depend on its specifications and job requirements. Some counters are simple frequency meters which only have to count to a couple of mega hertz, while others must count frequency, measure the period of the waveform, count events, or measure time-intervals. The specifications for frequency counters may include frequency range, the lowest to the highest frequencies the meter will have to count; input sensitivity, the smallest signal level the meter must be able to count; input impedance, its loading effect on whatever it is tied to; and finally, the meter's input protection, or what kind of signals (voltages) it can safely handle.

There are many types of counters, and each has a variety of features. There are also many specifications which relate to frequency counters. The best understanding of the frequency meter you are using in your lab is probably provided by its operation manual. Obtain this manual from your instructor and read it for a better understanding of frequency meters and their use.

SIGNAL GENERATORS

There are nearly as many different signal generators as there are different types of signals. The three basic generators which you might use in your study of electronics are the radio

1807

frequency generator, called an RF generator; an audio frequency generator, usually referred to as an AF signal generator; and finally, a function generator.

Figure G 4.1-1 is the front cover of a typical AF generator. An "audio frequency generator" is used to generate signals in the audio frequency range and above, typically 20 hertz to 200,000 hertz. It will usually generate a sine wave or a square wave whose output amplitude is variable from zero to about 20 volts peak to peak. The functions of the Controls 1 thru 5 on Figure G 4.1-1 are as follows: ONE is the variable frequency control used to vary the frequency from one end of the range to the other. TWO is a set of multiplier switches used to provide four ranges from 20 hertz to 200 kilohertz. THREE is a function switch which allows the operator to select a sine wave or square wave output. FOUR is simply a power switch. FIVE controls the amplitude of the output; it is usually variable from zero to 20 volts p-p.

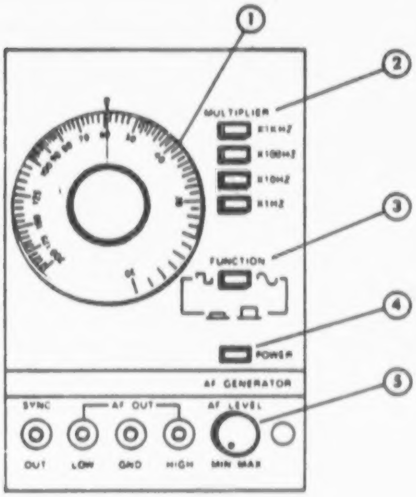

①
②
③
④
⑤
MULTIPLIER
X1KHZ
X100HZ
X10HZ
X1HZ
FUNCTION
POWER
AF GENERATOR
SYNC
AF OUT
AF LEVEL
OUT
LOW
GND
HIGH
MIN MAX

Figure G 4.1-1

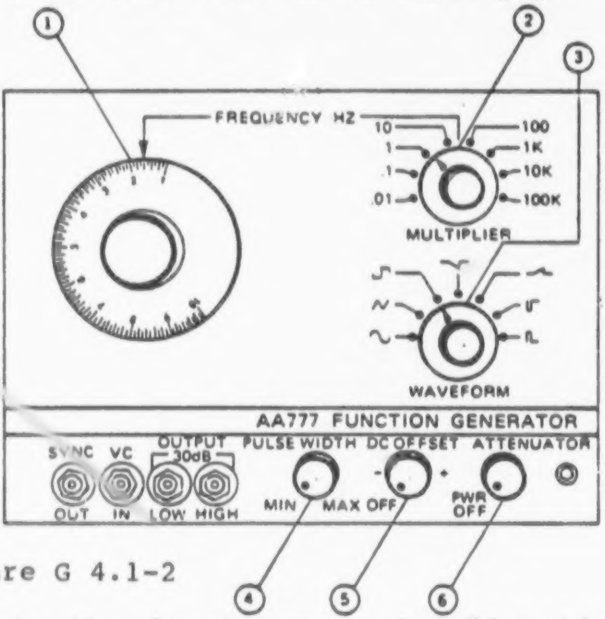

①
②
③
FREQUENCY HZ
10
100
1
1K
.1
10K
.01
100K
MULTIPLIER
WAVEFORM
AA777 FUNCTION GENERATOR
SYNC
VC
OUTPUT
30dB
PULSE WIDTH
DC OFFSET
ATTENUATOR
OUT
IN
LOW
HIGH
MIN
MAX
OFF
-
+
PWR
OFF
④
⑤
⑥

Figure G 4.1-2

Figure G 4.1-2 represents the front cover of a "function generator." The function generator is much like the audio generator with the exception of a few more functions (outputs). The controls are about the same as the AF generator except for THREE which allows the user to select a triangle waveform, two sawtooth waveforms, or inverted pulse waveforms. Control FIVE allows the user to place a DC component with the waveform selected. Usually the frequency range is a little greater on a function generator than on an AF generator; this one ranges from zero to one megahertz. The pulse output on the function generator makes it handy when troubleshooting digital logic circuits.

The last generator this guide will look at is the "radio frequency generator," or what is often simply called an RF generator. The RF generator is used to provide radio frequency signals which range approximately 500 kHz to several megahertz. Figure G 4.1-3 is an example of an RF generator. Control ONE is used to select the band of frequencies the generator can produce. Control TWO is a variable knob used to vary the frequency of the selected band. THREE is a power control. FOUR is different from the controls on an AF or function generator, in that it varies what is called the modulation of the frequency output. Modulation is the "intelligence" or change of the carrier. This control will have more meaning when you study radio frequency and communication circuits. The rest of the controls vary the amplitude of the signal and will vary from one generator to another.

There are many types of signal generators available to the electronics technician, and an explanation of each is beyond this guide. To familiarize yourself with the generator you will be using in the lab, ask your instructor for a copy of the operation manual, and read it for more information on signal generators.

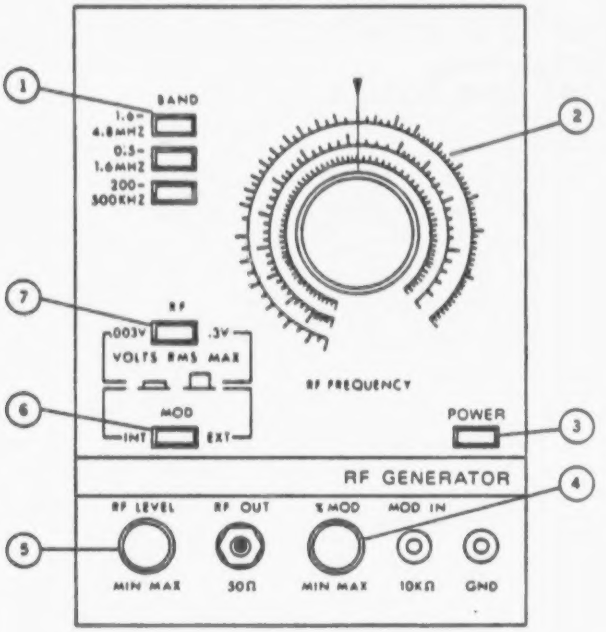

①
BAND
1.6-4.8MHZ
0.5-1.6MHZ
200-500KHZ
②
⑦
RF
.003V
.3V
VOLTS RMS MAX
RF FREQUENCY
⑥
MOD
INT
EXT
POWER
③
RF GENERATOR
④
RF LEVEL
RF OUT
% MOD
MOD IN
⑤
MIN MAX
50Ω
MIN MAX
10KΩ
GND

Figure G 4.1-3

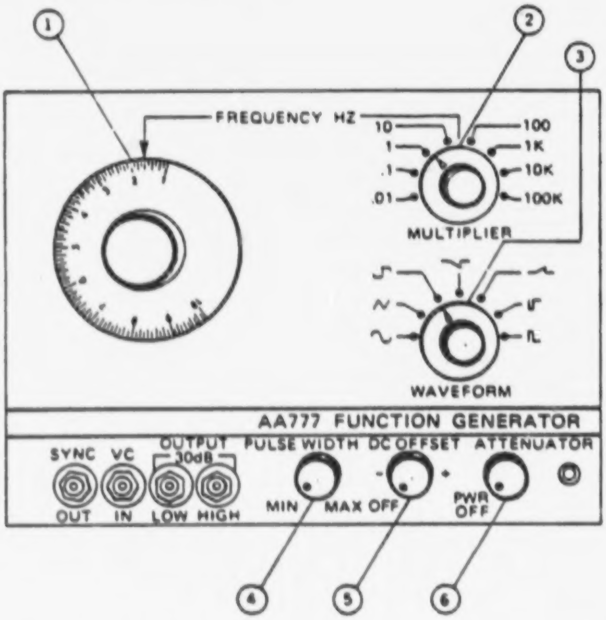
ACTIVITY SHEET

G 4.2

COUNTERS AND GENERATORS

On a separate sheet of paper complete all activities called for:

1. Drawn below is a signal generator. For each of the numbered controls, give its function and explain its effect on the operation.


①
②
③
FREQUENCY HZ
10
1
.1
.01
100
1K
10K
100K
MULTIPLIER
WAVEFORM
AA777 FUNCTION GENERATOR
SYNC
OUT
VC
IN
OUTPUT
30dB
LOW
HIGH
PULSE WIDTH
MIN
MAX
DC OFFSET
-
+
OFF
ATTENUATOR
PWR
OFF
④
⑤
⑥

2. Answer the questions below:

   (1) List the five basic functional blocks in an electronic counter.

   (2) Frequency is defined as:

   (3) Period is defined as:

   (4) A special oscillator produces one pulse every 10 microseconds. The frequency of the oscillator is:

   (5) An electronic counter's overrange display tells you what?

ACTIVITY SHEET G 4.2

ANSWER SHEET

1. (1) Frequency dial - a vernier dial for the selected range.
   (2) Range selection sheet - allows a range of frequencies to be selected.
   (3) Function switch - selects the waveform to be used.
   (4) Pulse width control - varies the width of the pulse output waveform.
   (5) DC offset - adds positive or negative voltage to the waveform.
   (6) Power and amplitude control - turns on power and varies amplitude of the waveform.

2. (1) List parts:

   a. decade counter and display circuits
   b. time-base oscillator
   c. divider chain
   d. gate and control circuits
   e. input amplifier and shaping circuits

   (2) Frequency is the number of cycles per second.

   (3) Period is the time required for one complete cycle.

   (4) 100khz

   (5) When it exceeds its count range.

PROGRAM: ELECTRONICS

TASK: SET UP AND OPERATE COUNTERS AND GENERATORS

TASK # G 4.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE __________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT __________

TERMINAL PERFORMANCE OBJECTIVE:

Set up and operate counters and generators.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 45 minutes and must score at least 17 out of 21 points or 80% for mastery. Critical items are marked with a an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 45 minutes and must score 17 out of 21 points or 80%, and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

SET UP AND OPERATE COUNTERS AND GENERATORS

G 4.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Set up the AF or function generator for 5K hertz square wave.	Y N
2.	Connect the output to a 600 DHM load.	Y N
3.	Set up the frequency counter to measure the output across this load.	Y N
4.	Record the generator's frequency from the range and frequency dial.	Y N
5.	Record the output count from the counter.	Y N
6.	Increase the frequency of the generator to 200KHZ and repeat steps 2 thru 5.	Y N
*7.	Return all equipment to proper storage.	Y N

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

SCORE ______

ELECTRONICS

PERFORMING LAB PRACTICES

G 5: SET UP AND OPERATE OSCILLOSCOPES

TASK:	Set up and operate oscilloscopes.
PURPOSE:	As an electronics technician you will be required to make many circuit measurements. Many of these measurements will be made by using an oscilloscope. After you complete this learning guide, you should understand the basic operation and use of a general purpose oscilloscope.
OBJECTIVE:	Given access to all necessary tools and equipment, set up and operate oscilloscopes. To master this task you must score 80% on a performance checklist and 80% on a written exam.

ESTIMATED CLASS TIME: 12 HOURS

SET UP AND OPERATE OSCILLOSCOPES

LEARNING STEPS

G 5

READ: Information Sheet G 5.1 on "The Scope."

READ: Information on oscilloscopes in one or more of the resources listed.

COMPLETE: Activity Sheet G 5.2 on "Scopes and Their Use."

COMPLETE: Lab performances on the oscilloscope. Contact your instructor.

COMPLETE: A review of all the material you have studied on oscilloscopes.

COMPLETE: Written Exam G 5.4 and Performance Checklist G 5.3. Contact your instructor.

SET UP AND OPERATE OSCILLOSCOPES

RESOURCES

G 5

1. Grob, BASIC ELECTRONICS (McGraw-Hill, 1984). Fifth Edition.
2. Zbar and Malvino, BASIC ELECTRONICS (McGraw-Hill, 1983). Fifth Edition.
3. Badrkhan and Larky, ELECTRONICS: PRINCIPLES AND APPLICATIONS, (South-Western Publishing Company, 1984).
4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS, (McGraw-Hill, 1984). Second Edition.
5. AC ELECTRONICS, (Heath Company, 1982). Nineteenth Printing.
6. INSTRUCTION AND OPERATION MANUAL FOR THE SCOPE IN YOUR LAB.
7. Tektronix, Inc., THE XYZ'S OF USING A SCOPE.

INFORMATION SHEET

G 5.1

THE SCOPE

An oscilloscope, which is often called a "scope," is a piece of test equipment which allows the user to measure voltage in reference to time. The scope "draws" the voltage waveforms as a two-dimensional graph on its cathode ray tube. The vertical axis of the graph represents the volts or amplitude of the waveform, and the horizontal axis represents the time or period of the waveform.

An oscilloscope's circuitry can basically be divided into four major parts: the vertical section controls the vertical deflection of the trace (waveform pattern); the horizontal section controls the time rate generator or horizontal sweep circuits; the trigger section controls the synchronization of the trace; and finally, the display section controls the intensity and focus of the trace. There are controls on the front panel of the scope to control these various circuit functions. Figure 1 is an example of a typical scope with each of its controls and inputs numbered. Not all scopes look like this one, but most scopes will have the same basic controls.

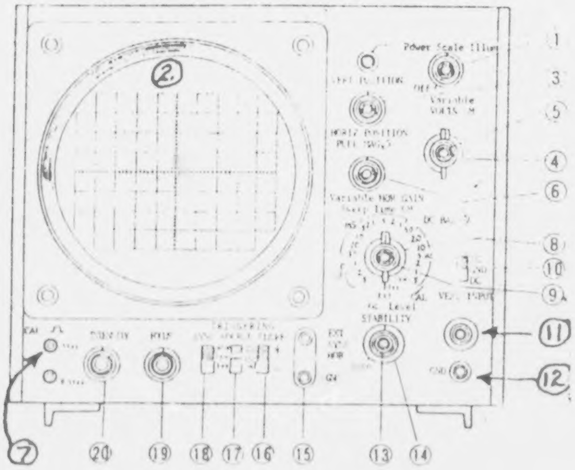

Power Scale Illum
1
2
3
Variable
5
HORIZ POSITION
4
6
Variable HOR GAIN
Sweep Time
8
10
9
CAL
VERT INPUT
STABILITY
11
GND
12
TRIGGERING
EXT
7
20
19
18
17
16
15
13
14

Figure G 5.1-1

The controls function as follows: (1) power switch and scale illumination control, used to turn the scope on and off and also to control the lighting on the "graticule" or screen; (2) the graticule, usually divided into centimeters, relates the vertical or horizontal deflection in cm per volt or cm per time period; (3) vertical position control, positions the trace up or down on the graticule; (4) volt/cm switch, short for volts per centimeter, sets the vertical deflection circuits to deflect the trace so many volts per centimeter (typical positions might be 1 volt per division or centimeter, .1 volt per centimeter, or 10 millivolts per centimeter). By varying this control you can "fit" the trace or signal on the screen; if your signal is too large for the screen, then you will want to increase the setting of this control to the next highest position; (5) the variable volts control, is usually the inside knob of the volts/division control and is put in a detent position and left alone. Doing this causes the vertical deflection circuits to be put in a "calibration position," which means you read the screen direct. If this variable control is not in the calibration position, the pattern on the screen is not calibrated to the screen and cannot be read for a particular volt/div setting; (6) the horizontal width pull for 5x magnification control, allows you to position the trace in the center of the screen. It also allows you to pull the knob and increase the horizontal and deflection by a factor of five; this feature is handy when it is necessary to "stretch" the trace for better viewing detail; (7) the probe calibration point output, is used to provide a source of calibrated voltage to adjust the probe compensation; (8) is the sweep time/cm control, which is used to set the sweep time of the horizontal deflection circuits. By varying this control the user is able to view one or two complete cycles of a waveform. This control will have positions marked in reference to time per divisions on the graticule. By counting the number of divisions one complete cycle or waveform occupies, and multiplying that time by the number of divisions, the user is able to measure the time period of the waveform; (9) the variable control for the time/div switch, is found inside the switch. It too has a detent position for calibration, and should be left in the detent or full clockwise position; (10) allows the user to select the input to the vertical deflection circuits. If it is coupled AC, then the scope will pass AC signals. If it is coupled DC, then the scope will "look" at the DC component of the waveform. And if it is coupled to ground (GND), the scope will ground the input to ground and there will be no deflection. This switch will allow the scope to be used like a DC voltmeter to measure the DC voltages present with reference to ground; (11) the vertical input point, is used to connect the probe to the scope; the connector used will vary from one manufacturer to another; (12) a ground connection point, is used to provide the user with a separate ground input other than that of the probe; (13) the trigger level control, is used to control the trigger circuits in the scope. It can be varied to allow for different trigger points. A trigger point is a point on the input signal used as reference to" trigger" or " sync" the trigger circuits in the scope; (14) the stability control is used with the trigger control to stabilize the waveform displayed on the scope's screen; (15) the external input, is provided for external trigger inputs. Normally the scope provides its own internal trigger; however, there are times when an external input will be applied; (16) the triggering slope switch, is used to set the trigger to a positive slope trigger, meaning the scope "syncs-up" on the positive side of the waveform; negative slope is just the opposite; (17) the trigger source control is used to set the source of the trigger for scope sync. This control may have a couple of settings such as Normal or External; (18) the triggering sync is used to "sync" the trigger of the scope with a signal. The settings will vary from scope to scope, but might include one or more of these: TV, Normal, P-P, External; (19) the focus control is used to focus or sharpen the trace for individual viewing; (20) the intensity control is used to control the brightness or the "intensity" of the trace. This control will be varied according to room lighting conditions.

One item which has not been covered, but which is one of the most important pieces of a scope, is the "probe." There are a variety of probes for different uses which are explained in great detail in manufacturers' literature. The most important thing to remember about a probe is that it is a very delicate device and must be treated with great care.

This information sheet is provided as an introduction to the oscilloscope, and not to be considered as all the information you need to know about the scope. You should contact your instructor for a copy of the operation and instruction manual for the scope you will be using in your lab, and read it from cover to cover to become completely familiar with your particular oscilloscope. The more you know about the scope and the easier you can use it, the better you will be at solving troubleshooting tasks in the lab.

ACTIVITY SHEET

G 5.2

SCOPES AND THEIR USE

On a separate sheet of paper complete all of the activities called for:

1. Briefly define the purpose of the following sections of an oscilloscope:

   A. horizontal section
   B. vertical section
   C. trigger section
   D. display section.

2. Match the following definitions and terms:

   ______ Controls the brightness of the electron beam.

   ______ Control which is used to align the horizontal waveform components with the horizontal lines of the graticule.

   ______ Inaccuracy caused by the displacement of the observer's eye from the plane of the measurement.

   ______ Vertical components of the oscilloscope graph.

   ______ System of lines etched on the inside of the CRT faceplate.

   ______ The horizontal components of the graph the scope draws.

   A. graticule
   B. y axis
   C. x axis
   D. intensity control
   E. parallax error
   F. trace rotation controls

ACTIVITY SHEET G 5.2 CONT'D.

3. Answer the following questions with a short answer:

   A. Why is a trace rotation control useful?

   B. Describe the functions of DC, AC, and GND settings on the input coupling control.

   C. What is the function of the variable VOLTS/DIV control?

   D. What is the function of the SEC/DIV control?

   E. What is line triggering and when would you use it?

   F. Are a probe's effects on the circuit constant?

ACTIVITY SHEET G 5.2

ANSWER KEY

1. The vertical system controls the vertical axis of the graph; anytime the electron beam that draws the graph moves up or down, it does so under control of the vertical system. The horizontal system controls the left to right movement of the beam. The trigger system determines when the oscilloscope draws; it triggers the beginning of the horizontal sweep across the screen. The display system contains the cathode-ray tube, where the graph is drawn.

2.

D
F
E
B
A
C

3.

A. Allows you to position the trace anywhere on the CRT screen.

B. DC input coupling lets you see all of an input signal. AC coupling blocks the constant signal components and permits only the alternating components of the input signal to reach the channel. The GND position disconnects the input signal from the vertical system and makes a triggered display showing the scopes's chassis ground. Using the GND position does not ground the signal in the circuit under test.

C. The CAL control in the center of the VOLTS/DIV switch provides a continuously variable change in the scale factor to a maximum greater than 2.5 times the volts/div setting. A variable sensitivity control is useful when you want to make quick amplitude comparisons on a series of signals.

D. The seconds/division switch lets you select the rate at which the beam sweeps across the screen; changing sec/div switch settings allows you to look at longer or shorter time intervals of the input signal. Like the vertical system volts/div switch, the control's markings refer to the screen's scale factors. If the sec/div setting is 1ms, that means that each horizontal major division represents 1ms and the total screen will show you 10ms.

ACTIVITY SHEET G 5.2 ANSWER SHEET CONT'D.

E. Line triggering means the scope's trigger signal is derived from its power line. Line triggering is useful anytime you're looking at circuits that are dependent on power line frequency.

F. No, a probe's impedance (resistance and reactance) changes with frequency.

PROGRAM: ELECTRONICS

TASK: SET UP AND OPERATE OSCILLOSCOPES

TASK # G 5.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT _______

DATE OF ATTEMPT ___________

OBJECTIVE:

Set up and operate oscilloscopes.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 45 minutes and must score at least 20 out of 25 points, or 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 45 minutes and must score 20 out of 25 points or 80%, and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

SET UP AND OPERATE OSCILLOSCOPES

G 5.3

CRITICAL ITEMS	ITEMS TO BE PERFORMED	RATING YES	NO
1.	Get out all necessary equipment and test leads.	Y	N
*2.	Set the signal generator for 5 volts peak to peak sine wave at 5KHz.	Y	N
*3.	Set up the scope and check the generators to make sure it is right. T=1/F T=______	Y	N
4.	Increase the amplitude of the generator; use the scope to measure the new amplitude.	Y	N
5.	Increase the frequency output of the generator and measure the new frequency with the scope.	Y	N
*6.	Set the generator for a square wave output of 5 volts P/P at 200 KHz.	Y	N
7.	Use the scope to measure the rise-time of this waveform.	Y	N
8.	Use the scope to set your DC power supply for 5 volts DC.	Y	N
*9.	Return all equipment and leads to proper storage area.	Y	N

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

SCORE ______

EXAM G 5.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on SCOPES AND THEIR USE. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Shade in the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on the ANSWER SHEET, using a #2 pencil to mark your answers. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

Match items 1-5 with the lettered items that are listed below.

1. _____ The functional block of a scope which controls the left to right and right to left movements of the electron beam.

2. _____ The functional block of a scope which controls when the oscilloscope starts to draw a trace.

3. _____ The functional block within the scope which controls the CRT.

4. _____ The functional block within the scope that controls the up and down movement of the electron beam.

5. _____ A finely-focused stream of electrons directed against the face of a CRT.

A. electron beam
B. trigger system
C. horizontal system
D. display system
E. vertical system

Match items 1-6 with the lettered items that are listed below.

6. _____ Vertical system control that allows you to vertically position the trace on the screen.

7. _____ Vertical system control which changes the sensitivity of the scope's vertical channel.

8. _____ The horizontal system control that determines the sweep rate.

9. _____ The trigger system control which determines whether a rising or falling edge is used as the trigger point.

10. _____ The trigger system control which determines the voltage level of the trigger point.

A. volts/div.
B. sec/div.
C. level
D. slope
E. position

EXAM KEY G 5.4

1. C
2. B
3. D
4. E
5. A
6. E
7. A
8. B
9. D
10. C

ELECTRONICS

PERFORMING LAB PRACTICES

G 6: SET UP AND OPERATE MULTIMETER AND POWER SUPPLIES

TASK:	Set up and operate multimeter and power supplies.
PURPOSE:	In the laboratory you will be required to build and test electronic circuits. This will require that you connect them to a source of power and measure circuit quantities. To do this, you will need to know how to use a multimeter and power supplies. After you complete this task, you should be able to connect a multimeter and a power supply to simple electronic circuits.
OBJECTIVE:	In a laboratory situation, given access to all necessary equipment, you will set up and operate multimeter and power supplies. To master this task you must score 80% on a written exam and 80% on a performance checklist.

ESTIMATED CLASS TIME: 12 HOURS

USING MULTIMETERS AND POWER SUPPLIES

LEARNING STEPS

G 6

READ: Information Sheet G 6.1 on "Multimeters and Power Supplies."

READ: Information on multimeters and power supplies from the following resource list.

COMPLETE: Activity Sheet G 6.2 on "Multimeters and Power Supplies."

COMPLETE: Lab performances on multimeters and power supplies. Contact your instructor.

COMPLETE: A review of all the material you have studied on multimeters and power supplies.

COMPLETE: Written Exam G 6.4 and Performance Checklist G 6.3. Contact your instructor.

MULTIMETERS AND POWER SUPPLIES

G 6

RESOURCES

1. Grob, BASIC ELECTRONICS, (McGraw-Hill, 1984). Fifth Edition.
2. Zbar and Malvino, BASIC ELECTRONICS, (McGraw-Hill, 1983). Fifth Edition.
3. Badrkhan and Larky, ELECTRONICS: PRINCIPLES AND APPLICATIONS, (South-Western Publishing Company, 1984).
4. Schuler, ELECTRONICS PRINCIPLES AND APPLICATIONS, (McGraw-Hill, 1984). Second Edition.
5. AC Electronics, (Heath Company, 1982). Nineteenth Printing.
6. VOM and Power Supply Operation and Instruction Manual; contact your instructor.

INFORMATION SHEET

G 6.1

MULTIMETERS AND POWER SUPPLIES

POWER SUPPLIES

A power supply is used to provide a voltage to a circuit. There are many times that a circuit will require a voltage other than 120 volts AC (line voltage). When this is the situation, the technician will need to use a power supply to provide this new voltage. Power supplies can be purchased for almost any application which might be desired; however most situations will require some form of DC voltage, and this can be provided by a general purpose power supply.

Several "standard" features might be found on a general purpose power supply. First, there should be a source of variable DC from zero to 25 volts. This source might be regulated. "Regulation" refers to the supply's ability to maintain a set voltage regardless of the load connected to it. Another feature which should be present is some sort of variable AC voltage, which will vary the voltage from zero to 120 volts. A third feature might be a set of fixed AC voltages rated at vacuum tube levels (6.3 and 12.6 volts). A fourth feature might be a "tightly regulated" source of low voltage DC used for transistor bias. This source will generally have some sort of "current limiting," which is a means of presetting the current available to the load to some value. This is a nice feature to use when the circuitry you are working on is very expensive and too much current would destroy it. A fifth feature is a split or bi-polar supply. A "split supply" is a supply with a positive voltage and a negative voltage referenced to a common ground. This type of supply is used when a technician is working with operational amplifiers. These features will be found on some power supplies but not all. The amount of voltages, the types of voltages, and the precision of the voltages will depend on the cost of the power supply. For information about the power supply you will be using in your lab, you should contact your instructor for a copy of the operation and specification manual for your power supply or supplies.

MULTIMETERS

A multimeter is a meter which measures multiples of such things as ohms, volts, and milliamps. A common term for a multimeter is VOM, which is short for volt-ohm-millammeter. A VOM can be either analog or digital. An analog VOM is a needle movement type, where the digital has a 3 or 4 digit display for read out. The controls on a VOM can be divided into two basic groups, function and range. The function controls determine the function of use (AC volts or current, DC volts or current, and ohms).

The range is used to select the highest quantity which can be measured on that setting (0 to 1 volt, 0 to 10 volts, etc.). Figure G 6.1-1 is an example of an analog VOM.

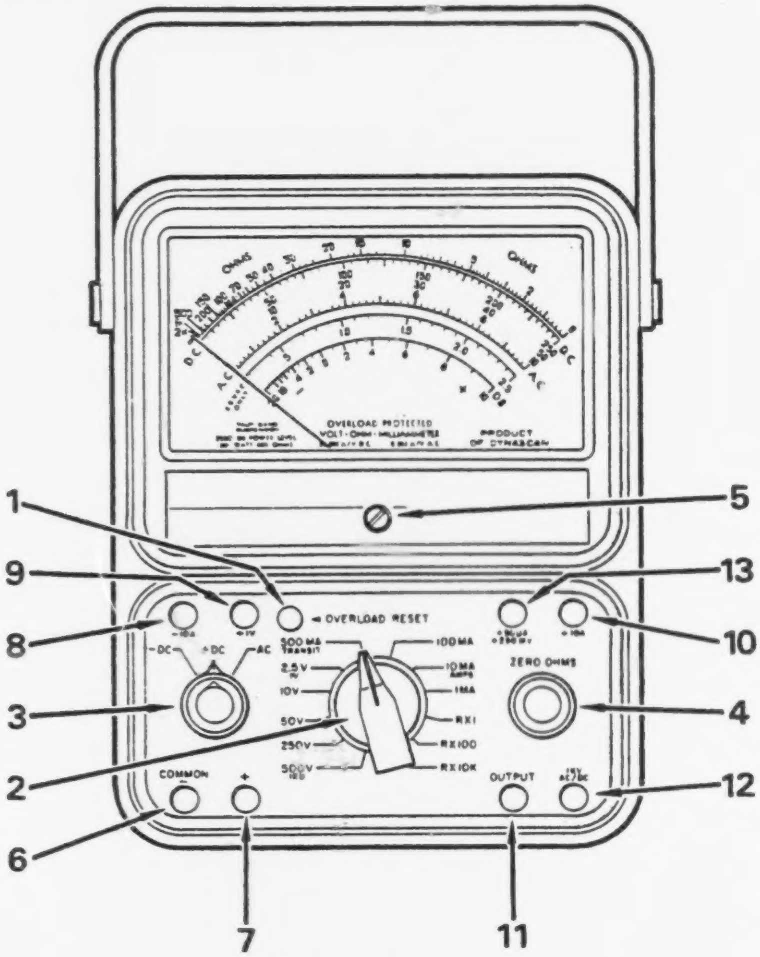

OHMS
DC
AC
OVERLOAD PROTECTED
VOLT-OHM-MILLIAMMETER
PRODUCT OF DYNASCAN
1
5
9
13
8
10
OVERLOAD RESET
-DC
+DC
AC
500 MA
100 MA
2.5V
10 MA AMPS
10V
1MA
50V
RX1
250V
RX100
500V
RX10K
ZERO OHMS
3
4
2
12
COMMON
+
OUTPUT
6
7
11

Figure G 6.1-1

Each of the numbers represents a control or an input. (1) This is an overload reset button which will "pop" if the meter is accidentally overloaded; (2) this rotary switch serves to set the range and the function. Starting at the position indicated by the knob and working clockwise, the settings are as follows: 500MA is a current measurement position which allows for a reading of from 0 to 500 mA of current. The next three positions are also current settings for values of 100, 10 and 1 mA of current. Some meters will allow you to measure AC or DC on these ranges, depending on the setting of the AC/DC switch. The next three positions (RX1 thru RX10K) are ohms measuring ranges, which allow you to measure resistance. These settings use the top scale on the meter, which is logarithmic. The last five positions on the switch are for measuring voltage and will be used for both AC and DC voltages, depending on the setting of Control Number 3; (3) this control is used to select either AC or positive or negative DC. The +DC and -DC switch is a nice feature which can be used if you happen to hook your test leads into the circuit with the wrong polarity; (4) this is a knob used to zero the meter for resistance measurements. This allows for changes in battery voltages and test lead resistance; (5) this is a mechanical adjustment to position the meter's needle on the zero mark; (6), (7) these are inputs for the test leads; (8) here is a special input when measuring currents up to 10 amps. This position will provide a shunt for the larger current; (9) this is another special input for the red test lead, which is used to measure voltage of 1 volt or less. The smallest range on the switch is a zero to 2.5 volt range; (10) here is a positive 10 amp shunt as opposed to the negative one of number 8; (11) this is an output jack used to measure AC signal voltages; (12) this is a special 1 kilovolt input used when measuring AC or DC voltages of up to 1000 volts; (13) the last of the special inputs is for measuring small currents (50 microamps) and small voltages (250 millivolts). Not all VOMs look like this one or have the same features and controls; however, this example is typical of most of the analog VOMs you might have access to.

When using a VOM to measure circuit quantities, there are a few general things to remember. If you are measuring current, the meter must be put in series in the circuit. This will usually require you to break the circuit physically and insert the meter. When you are measuring voltage with a meter, the meter will simply be placed in parallel with the device or voltage you wish to measure. Measuring resistance will require that all power to the circuit be removed; failure to do so will damage the meter. One consideration which must be given when using an analog VOM is circuit loading. This will not usually be a problem with an electronic VOM or a digital VOM due to its high input impedance.

This information sheet provides only a general introduction. You should ask your instructor for a copy of the instruction and operation manual for the VOM you will be using. After receiving this manual, you should read it from cover to cover until you understand how to use your VOM safely.

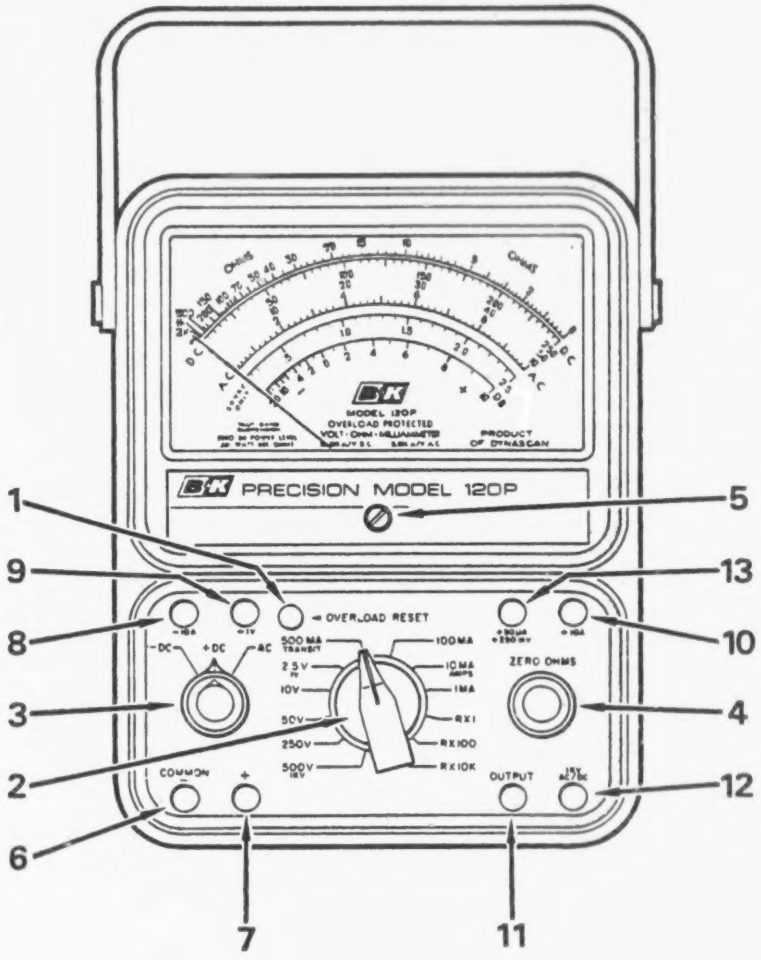
ACTIVITY SHEET

G 6.2

MULTIMETERS AND POWER SUPPLIES

On a separate sheet of paper complete all of the activities called for:

1. Identify the function of each input or control on the diagram shown below.



B+K
MODEL 120P
OVERLOAD PROTECTED
VOLT · OHM · MILLIAMMETER
PRODUCT OF DYNASCAN
B+K PRECISION MODEL 120P
1
5
9
13
8
10
3
4
2
12
6
7
11
OVERLOAD RESET
-DC
+DC
AC
500 MA TRANSIT
2.5V
10V
50V
250V
500V
100MA
10MA
1MA
RX1
RX100
RX10K
ZERO OHMS
COMMON
−
+
OUTPUT

2. A voltmeter is connected in ____________________ in order to take a circuit voltage measurement.

ACTIVITY SHEET G 6.2 CONT'D.

3. An ammeter is connected in ____________________ in order to take a circuit current measurement.

4. To check the resistance of a circuit you must first do what?

5. Draw the front panel of your power supply and label the inputs and controls.

ACTIVITY SHEET G 6.2

ANSWER KEY

1. See Instruction/Operation manual.
2. Parallel
3. Series
4. Disconnect the circuit power
5. Depends on individual power supply

PROGRAM: ELECTRONICS

TASK: SET UP AND OPERATE MULTIMETERS AND POWER SUPPLIES

TASK # G 6.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE __________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT __________

OBJECTIVE:

Set up and operate multimeters and power supplies.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 45 minutes and must score at least 16 out of 20 points, or equivalent to 80% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 45 minutes and must score 16 out of 20 points or an equivalent of 80%, and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

SET UP AND OPERATE MULTIMETERS AND POWER SUPPLIES

G 6.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES	NO
1.	Obtain all necessary equipment.	Y	N
*2.	Using the VOM, set the variable DC supply for 12 volts.	Y	N
*3.	Breadboard a series circuit with 3 100 ohm resistors and connect it to 9 volts DC.	Y	N
4.	Using the VOM, measure the circuit current.	Y	N
5.	Using the VOM, measure the voltage across each resistor.	Y	N
*6.	Disconnect the power from the circuit and measure the circuit resistance.	Y	N
*7.	Shut off the power and return all equipment to proper storage area.	Y	N

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

SCORE ______

EXAM G 6.4

DIRECTIONS:

The purpose of this exam is to determine whether or not you have understood the information on VOM's and power supplies. Each of the questions or incomplete statements is true or false. Shade in the letter associated with that choice (A for True or B for False) in the numbered blank space on the ANSWER SHEET, using a #2 pencil to mark your answers. DO NOT WRITE ON THIS TEST! To master this exam you must answer 8 out of 10 items correctly, (80%).

EXAM G 6.4 CONT'D.

1. Most electronic circuits use only 120 volts AC.

   A. True
   B. False

2. Regulation refers to the supply's ability to maintain a constant voltage regardless of the load connected to it.

   A. True
   B. False

3. A 20,000 ohm/volt VOM will not load a high resistance circuit.

   A. True
   B. False

4. A bi-polar power supply usually has two equal and opposite voltages in reference to ground.

   A. True
   B. False

5. When using a VOM to measure current, connect the meter across the component carrying the current.

   A. True
   B. False

6. When measuring resistance with a VOM, it is not necessary to re-zero the meter on a new resistance range.

   A. True
   B. False

7. The power to a circuit must be removed when measuring circuit resistance.

   A. True
   B. False

8. The voltage scale on a VOM is usually logarithmic.

   A. True
   B. False

9. A voltage measurement is usually taken by placing the meter across (parallel) with the component consuming the voltage.

   A. True
   B. False

10. When taking a resistance measurement with the VOM on the RX1 setting, the scale is read direct.

   A. True
   B. False

EXAM KEY G 6.4

1. B
2. A
3. B
4. A
5. B
6. B
7. A
8. B
9. A
10. A

ELECTRONICS

PERFORMING LABORATORY PRACTICES

G 7: IMPEDANCE BRIDGE

TASK: Operate an impedance bridge.

PURPOSE: The impedance bridge is a piece of electronic test equipment that is capable of measuring the inductance, capacitance, resistance, and conductance of electronic devices and is used to identify, measure and test such devices. This learning guide will explain the terms and processes necessary to understand and use this equipment.

OBJECTIVE: Given a set of electronic components, you will correctly measure at least 81% of the devices within 10 minutes.

ESTIMATED CLASS TIME: .5 HOUR

OPERATION OF IMPEDANCE BRIDGE

LEARNING STEPS

G 7

READ: Information Sheet G 7.1, "Impedance Bridge."

COMPLETE: Activity Sheet G 7.2, "Impedance Bridge."

READ: Information on the operation of the impedance bridge in the operators' manual.

REVIEW: Information Sheet G 7.1 and Activity Sheet G 7.2.

COMPLETE: Laboratory performance on impedance bridge operation. Contact your instructor.

COMPLETE: Performance Checklist G 7.3.

COMPLETE: Practical Examination G 7.4 for mastery of this task.

IMPEDANCE BRIDGE

G 7

RESOURCES

1. Equipment Operational Manual(s)
2. Component Specification Manuals

REQUIRED EQUIPMENT

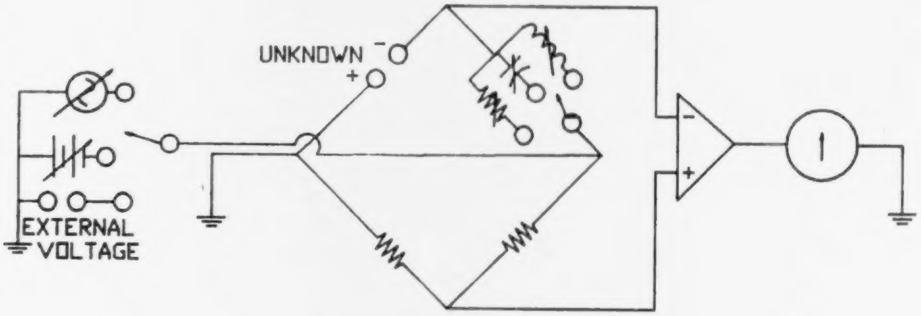
Impedance Bridge

INFORMATION SHEET

G 7.1

IMPEDANCE BRIDGE

The operation of an impedance bridge is identical to the operation of any other bridge circuit. When the current flowing through each side of the bridge is identical, the components on each side of the bridge have identical characteristics. Thus it is possible to check the operation of resistors, capacitors, and inductors by placing the unknown device in one side of a bridge and comparing it to a "known good device" on the other side of the bridge. Often the known good device is a highly accurate adjustable resistor, capacitor, or inductor. A schematic diagram of a simple bridge is shown below:



An operational amplifier is connected across the bridge to increase the sensitivity and thus the accuracy of the device. The operational amplifier is connected to a zero-center meter movement. The unknown component is connected to the bridge for testing. The proper settings are made to the impedance bridge for the component being tested. For example, resistors are usually tested with a DC voltage applied, while capacitors are tested with an AC voltage. This device is sensitive enough to measure the inductance of a wire wound resistor. This test would be performed with AC applied to the resistor and the bridge set to test for inductance.

The typical impedance bridge can test for resistance and conductance, capacitance with either series or parallel resistance, and inductance with either series or parallel resistance.

ACTIVITY SHEET G 7.2

DIRECTIONS:

Complete the table below using the impedance bridged as specified in the Operating Manual(s). If the item measures within its stated tolerance, it is good; if not, it is bad.

IMPEDANCE BRIDGE RESULTS

ITEM AND NUMBER		RATED VALUE	MEASURED VALUE	GOOD/BAD
RESISTORS	1			
	2			
	3			
CAPACITORS	1			
	2			
	3			
INDUCTORS	1			
	2			
	3			

PROGRAM: ELECTRONICS

TASK: Operate an impedance bridge

TASK# G 7.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

OBJECTIVE:

Operate an impedance bridge.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must score at least 80 out of 100 points, or achieve a score equivalent of 80% for mastery.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 80 out of 100 points, or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

OPERATE AN IMPEDANCE BRIDGE

G 7.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING	
		YES	NO
1.	Was 100% of experiment completed?	Y	N
2.	Did experiment function as designed?	Y	N
3.	Was required equipment used?	Y	N
*4.	Was required data recorded?	Y	N
5.	Was equipment used according to specifications?	Y	N
*6.	Were all safety precautions followed?	Y	N
7.	Was equipment returned to proper storage area?	Y	N
*8.	Was experiment summarized properly?	Y	N

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

SCORE _____

Any check in the "no" column for a critical item is an automatic failure for this module.

EXAM G 7.4

DIRECTIONS:

Complete the table below using the numbered items. The impedance bridged is to be used as specified in the operating manual(s). If the item measures within its stated tolerance, it is good; if not, it is bad. This is a timed test; you have ten (10) minutes for completion.

IMPEDANCE BRIDGE RESULTS

ITEM AND NUMBER		RATED VALUE	MEASURED VALUE	GOOD/BAD
RESISTORS	1			
	2			
	3			
CAPACITORS	1			
	2			
	3			
INDUCTORS	1			
	2			
	3			

EXAM KEY G 7.5

DIRECTIONS:

Complete the table below using the numbered items. The impedance bridged is to be used as specified in the operating manual(s). If the item measures within its stated tolerance, it is good; if not, it is bad. This is a timed test; you have ten (10) minutes for completion.

IMPEDANCE BRIDGE RESULTS

ITEM AND NUMBER		RATED VALUE	MEASURED VALUE	GOOD/BAD
RESISTORS	1			
	2			
	3			
CAPACITORS	1			
	2			
	3			
INDUCTORS	1			
	2			
	3			

INSTRUCTOR'S NOTE: The items tested and the type of bridge used require that you complete the answer sheet using the numbered items and the bridge.

ELECTRONICS

PERFORMING LAB PRACTICES

G 8: SET UP AND OPERATE CAPACITOR INDUCTOR ANALYZERS

TASK:	Set up and operate capacitor inductor analyzers.
PURPOSE:	To be able to measure capacitance accurately, you need to understand how to use special equipment. In this learning guide you will set up and operate capacitor inductor analyzers.
OBJECTIVE:	Given access to all necessary tools and equipment, you will set up and operate capacitor-inductor analyzers. To master this task you must achieve a score equivalent of 80% on a performance checklist.

ESTIMATED CLASS TIME: 3 HOURS

CAPACITOR INDUCTOR ANALYZERS

LEARNING STEPS

G 8

READ:	Information Sheet G 8.1 on "Capacitor Inductor Analyzers."
VIEW:	Audio/Visual material on capacitor inductor analyzers. See your instructor.
READ:	Instruction manual to capacitor inductor analyzer. See your instructor.
COMPLETE:	Activity Sheet G 8.2 on "Capacitor Inductor Analyzers."
REVIEW:	All materials in this guide.
COMPLETE:	Performance/Product Checklist G 8.3. See your instructor.

CAPACITOR INDUCTOR ANALYZERS

G 8

RESOURCES

- Operating and instruction manual for the capacitor inductor analyzer.

INFORMATION SHEET

G 8.1

CAPACITOR INDUCTOR ANALYZERS

In order to measure capacitance inductance in a circuit, you need to know how to use various pieces of test equipment. Each style or brand of test equipment may vary, so it is important to read the instruction manual that accompanies your particular meter.

Most manuals include general specifications about the test equipment. A description of various important parts of the test equipment may be included.

Usually the manual will also include basic operating instructions on how to use your meter properly. Along with understanding the operations of your meter, you need to become familiar with general maintenance (care) and calibration of the meter. Many times this information is located in the instruction manual.

Many different manufacturers produce the same type of test equipment, so it is important to get to know your brand well. There are "do's and don'ts" that come with almost every different type.

To understand how to use your particular analyzer, find the instruction manual and continue with this learning guide.

ACTIVITY SHEET

G 8.2

CAPACITOR INDUCTOR ANALYZERS

1. What features does your analyzer display?
2. List the general specifications of your analyzer.
3. Draw a picture of your analyzer and label all of its various controls and important features.
4. List any special considerations that accompany your test analyzer.
5. List good maintenance procedures for your analyzer.

ACTIVITY SHEET G 8.2

ANSWER KEY

CAPACITOR INDUCTOR ANALYZERS

Questions 1-5: All answers should contain specific information about the particular type of test analyzer that is used in the lab. The answers may be found in the instruction manual for the test analyzer.

PROGRAM: ELECTRONICS

TASK: SET UP AND OPERATE CAPACITOR INDUCTOR ANALYZERS

TASK# G 8.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE __________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT __________

OBJECTIVE:

Set up and operate capacitor inductor analyzers.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must score at least 80 out of 100 points, or achieve a score equivalent of 80% for mastery.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 80 out of 100 points, or 80%. All items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

SET UP AND OPERATE CAPACITOR INDUCTOR ANALYZERS

G 8.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
1.	Was the circuit wired according to the schematic?	Y	N
*2.	Does the circuit function properly?	Y	N
3.	Was necessary data recorded?	Y	N
*4.	Was the correct equipment used?	Y	N
*5.	Was the equipment used correctly?	Y	N
*6.	Were safety precautions followed?	Y	N
7.	Was the equipment returned to proper storage area?	Y	N

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

SCORE ______

ELECTRONICS

PERFORMING LAB PRACTICES

G 9: SEMICONDUCTOR TESTERS

TASK:	Set up and operate semiconductor testers and curve tracers.
PURPOSE:	To check semiconductors accurately you must have knowledge of special equipment, i.e., transistor checkers and curve tracers. In this learning guide you will be introduced to semiconductor test equipment operations and applications.
OBJECTIVE:	Given access to all necessary tools and equipment, you will set up and operate semiconductor testers and curve tracers. To master this task you must achieve a score equivalent to 80%.

ESTIMATED CLASS TIME: 1 HOUR

LEARNING STEPS

G 9

Semiconductor Testers

READ: Information Sheet G 9.1 on "Semiconductor Test Equipment."

READ: Instruction Manual for transistor checker and curver tracer. See your instructor.

VIEW: Audio/visual on the operation of semiconductor test equipment. See your instructor.

COMPLETE: Activity Sheet G 9.2 on "Semiconductor Testers."

REVIEW: All material in this guide.

COMPLETE: Performance/Product Checklist G 9.3. See your instructor.

COMPLETE: Written Exam G 9.4.

SEMICONDUCTOR TESTERS

G 9

RESOURCES

The resources used to operate semiconductor test equipment and curve tracers should be the instruction manual.

INFORMATION SHEET

G 9.1

SEMICONDUCTOR TEST EQUIPMENT

Most semiconductor testers can be used in one or two ways - (1) in the circuit or (2) out of the circuit. The model used in your lab will determine what semiconductor characteristics you can measure. A typical tester may be able to:

1. Determine good or bad transistors, FET's or SCR's, in- or out-of-circuit.
2. Determine good or bad diodes in- or out-of-circuit.
3. Identify Emitter-Base-Collector leads of transistors.
4. Identify gate lead of FET's.
5. Indicate polarity of good devices (NPN or PNP; N or P Channel).
6. Identify Cathode-Gate-Anode leads of SCR's.
7. Indicate whether silicon or germanium.
8. Measure I_{CES} or I_{BES} of transistors.
9. Measure I_{DSS} and gate leakage of FET's.
10. Measure reverse leakage current of diodes.
11. Determine whether device is transistor, FET or SCR.

One example of a semiconductor tester may look like the tester shown in Figure G 9.1-1.

1864

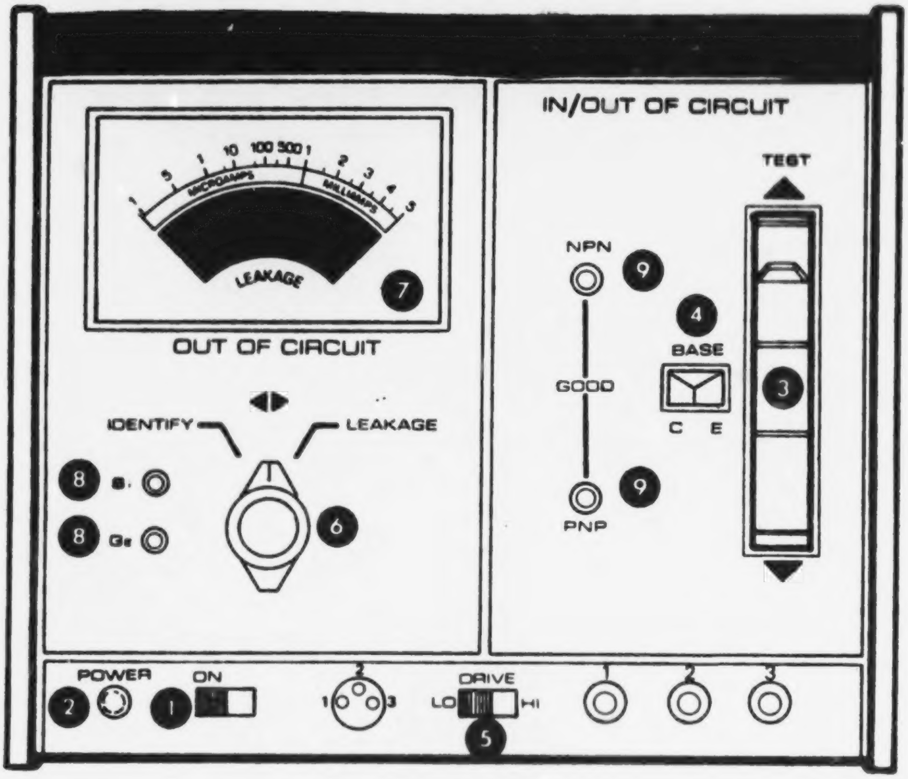

1
5
1
10
100
500
1
2
3
4
5
MICROAMPS
MILLIAMPS
LEAKAGE
7
OUT OF CIRCUIT
IDENTIFY
LEAKAGE
8
Si
8
Ge
6
IN/OUT OF CIRCUIT
TEST
NPN
9
4
BASE
GOOD
C
E
3
9
PNP
POWER
ON
2
1
1
2
3
DRIVE
LO
HI
5
1
2
3

Figure G 9.1-1 Front panel showing controls and indicators.

CONTROLS AND INDICATORS

1.	POWER ON Switch:	Applies power.
2.	POWER ON Lamp:	Indicates power is ON.
3.	TEST Switch:	Selects proper device connection for testing and lead identification.
4.	Lead Identification Window:	Identifies leads by color.
5.	DRIVE Switch:	Selects LO or HI base drive.
6.	FUNCTION Switch:	Spring-return switch selects either of two additional tests:

INFORMATION SHEET G 9.1 CONT'D.

	a. I_{CES} or I_{BES} for transistors; I_{DDS} and gate leakage for FET's. b. Identifies device material (silicon or germanium).
7. LEAKAGE Meter:	Indicates device leakage current. a. Indicates safe leakage limits for typical silicon and germanium transistors. b. Indicates I_{DSS} and gate leakage for FET's.
8. IDENTIFY Lamps:	Indicate silicon or germanium device.
9. NPN and PNP Lamps:	Indicate polarity of good devices.
10. AUDIBLE TONE:	Indicates good device.

IDENTIFYING TRANSISTORS AND DIODES

When using a semiconductor tester it is important to know the following information:

1. Nearly all germanium transistors come in metal cases, either the tubular type with flexible leads, or in the standard TO-5 package.
2. Power transistors in stud packages or in the TO-5 or TO-3 can be either germanium or silicon, depending on age. Two and three digit 2N-numbers are mostly germanium.
3. The TO-66 power transistors and the plastic power tab packages are nearly always silicon. The collector is usually, but not always, connected to the mounting tab and the center lead.
4. The base lead of most modern plastic type transistors is either the center lead or the right hand lead when facing the flat side with the leads down. In the latter case the collector lead is in the middle.

INFORMATION SHEET G 9.1 CONT'D.

5. Most plastic FET's have the gate lead on the right side when facing the flat side with the leads down, and the source in the middle, but there are exceptions. With nearly all junction FET's, the source and drain can be interchanged with no adverse effects.

6. All transistors will have some gain with the collector and emitter leads interchanged, with the exception of Darlingtons.

7. Germanium signal diodes can usually be recognized by their transparent hollow glass cases with either three or four color bands or type numbers printed on them. Silicon diodes are usually painted because silicon is light sensitive and must be protected from ambient light. The "moose" types, such as the stud package, can be either germanium or silicon.

You must also remember that there may be some semiconductor testers that cannot check special semiconductors (i.e., triacs, diacs, or diode arrays). Your equipment may have other "special" considerations. So, when in doubt, check the instruction manual.

Generally, to use a semiconductor tester you attach test leads to the semiconductor to be checked. Of course you must familiarize yourself with your particular model of test equipment. Be sure to read all of the instruction manual.

Watch for "special notes" in the instruction manual, i.e.:

IN-CIRCUIT TESTING

CAUTION: Make sure all power is turned off in the circuit being tested, and that all capacitors are discharged.

OR

HINT: A can of "Instant Cold Spray" is quite useful for providing rapid cooling of discrete components.

CALIBRATION AND SERVICE

Sometimes with a lot of use, a tester may need to be calibrated or serviced. If so, again your instruction manual may give some hints to follow. If not, you may have to send the equipment back to the manufacturer for servicing.

Curve Tracers

The semiconductor curve tracer displays a family of dynamic characteristic curves for transistors, FET's, diodes, Zener diodes, triacs, tunnel diodes and all other semiconductor devices on the screen of an oscilloscope. Most authorities agree that a dynamic curve tracer is the best instrument for testing semiconductors, since it simulates actual operating conditions of changing voltage and current. Some of the characteristics which may be measured are gain (beta), leakage, breakdown voltage, output admittance, linearity, effects of capacitance and effects of temperature.

When first introduced, semiconductor curve tracers were primarily employed in engineering laboratories to select transistors with specific characteristics for design applications. Later the instruments became widely used for sorting, inspecting and testing semiconductors in production assembly and by technicians for troubleshooting. The latest application has been the discovery that curve tracers can be used for troubleshooting without removing the semiconductor from the circuit. In addition, a semiconductor curve tracer offers several other servicing advantages. By matching characteristics, balanced and/or complementary pairs may be selected. Matching also allows sorting and selection of transistors for substitution, resulting in an inventory reduction of replacement parts.

An oscilloscope must be used in conjunction with the curve tracer for the display. Almost any 3-inch or larger general purpose oscilloscope is satisfactory as long as it has external horizontal facilities, and is DC coupled. A graticule overlay for the oscilloscope screen and built-in calibration signals from the curve tracer makes the unit complete.

The special 3-tip probe supplied with the unit simplifies in-circuit testing by contacting base, collector and emitter simultaneously with a single probe. This is very convenient for testing transistors mounted on circuit boards.

GENERAL DESCRIPTION OF INSTRUMENT OPERATION

The semiconductor curve tracer is essentially a signal generator that generates precision test signals for application to a semiconductor, the results of which are displayed on an oscilloscope. See Figure G 9.1-2.

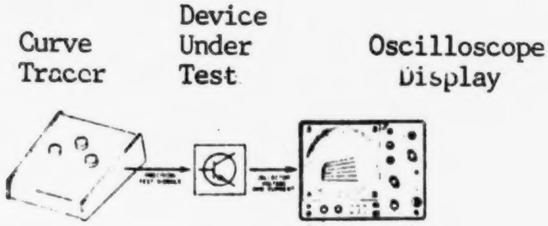


Figure G 9.1-2 Basic Curve Tracer Operation

The curve tracer generates two signals that are applied to the semiconductor device under test. One signal is a variable amplitude 120 Hz sweep voltage (full-wave rectified DC) which is normally applied to the collector. The other signal consists of constant-current steps which are normally applied to the base. For FET's, constant-voltage steps rather than constant-current steps are generated and applied to the gate.

The 120 Hz sweep voltage is continuously adjustable from 0 to 100 volts peak with the SWEEP VOLTAGE control. This pulsating dc voltage is of positive polarity when the POLARITY switch is set to NPN (N CHAN) and of negative polarity when the switch is set to PNP (P CHAN).

The step generator signal consists of five constant-current steps plus a zero-current step. The STEP SELECTOR switch offers 11 settings from 1 µA to 2 mA per step to match normal operating conditions for a full range of transistor types. For example, with the STEP SELECTOR switch set at 50 µA per step, the current steps are 0, 50µ , 100µ , 150µ , 200µ and 250µ , then repeated. When the POLARITY switch is in the NPN position, the steps are of positive polarity; in the PNP position, negative polarity. In the VOLTS PER STEP positions of the STEP SELECTOR switch, constant-voltage steps are generated for testing FET's. Five selections from .05 to 1 volt per step are offered. The polarity of the voltage steps is inverted in relation to the current steps. That is, the N CHAN position produces negative voltage steps, and the P CHAN position produces positive voltage steps (reverse bias steps are required for testing FET's).

The sweep voltage that is applied to the collector of the transistor is also applied to the horizontal input of the oscilloscope. As the voltage increases from zero to maximum and returns to zero, a horizontal sweep is produced. A precision resistor in series with the sweep voltage source develops a voltage that is proportional to the resultant collector current.

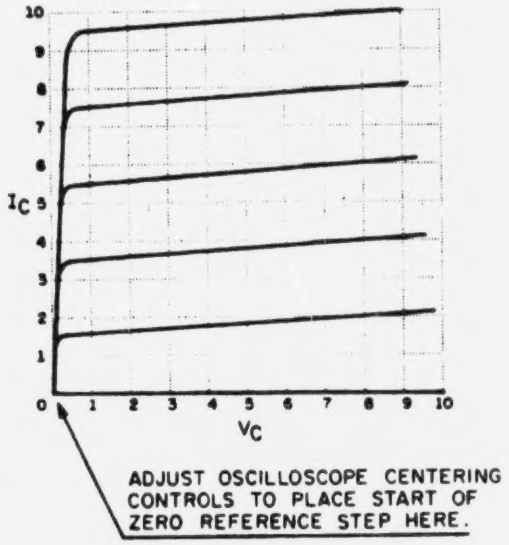
INFORMATION SHEET G 9.1 CONT'D.

The voltage developed across this resistor is applied to the vertical input of the oscilloscope; therefore, vertical deflection represents collector current. Actually, four different precision resistors are included and selected by the VERTICAL SENSITIVITY switch on the curve tracer. This allows greater versatility for displaying a wide range of collector currents.

The steps of the step generator are synchronized with the pulses from the sweep generator. The base current remains at a fixed value while the sweep voltage increases from zero to maximum and returns to zero. The base current then steps to the next higher fixed value while the sweep voltage completes another cycle. The result is a family of six curves, one for each step, with each base current step increase producing a higher collector current. The display is a dynamic collector current (Ic) vs. collector voltage (Vc) graph.

An NPN and PNP transistor on a semiconductor curve tracer may look like this:

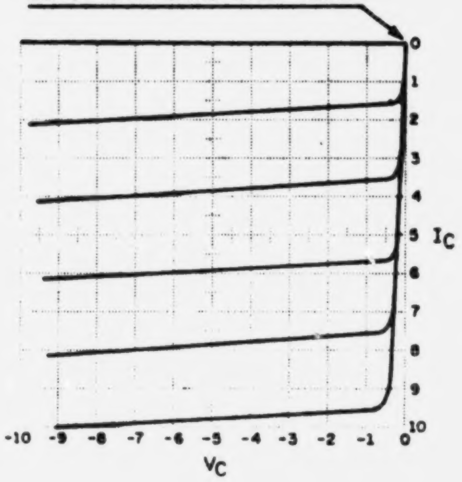
NPN



ADJUST OSCILLOSCOPE CENTERING CONTROLS TO PLACE START OF ZERO REFERENCE STEP HERE.

PNP

ADJUST OSCILLOSCOPE CENTERING CONTROLS TO PLACE START OF ZERO REFERENCE STEP HERE.



The curve tracer applies a stepped current (I_B) to the base of the transistor while a sweeping voltage (V_{CE}) is applied to the collector of the transistor.

Most curve tracers operate similarly, but instructions may differ from one manufacturer to another.

Familiarization with the Curve Tracer

To become familiar with using the curve tracer, gather an assortment of good semiconductor devices and test them one by one, observing the normal results, effects of readjusting the controls, peculiarities of various semiconductors, etc. Emphasis should be placed on recognizing normal and abnormal displays and how to set the curve tracer controls to obtain a normal display.

The user should become familiar with the normal results obtained by testing semiconductors out-of-circuit before starting to use the curve tracer for in-circuit testing.

Transistors and other semiconductor devices are tested with respect to manufacturers' specification sheets, which state certain conditions of the test and minimum performance standards. It should be realized that it is normal for characteristics of some devices to vary quite widely from one semiconductor to another although they have the same type number. However, manufacturers' specification sheets are not always readily available. Additionally, the manufacturer and type number are not always easily determined. Nevertheless, the semiconductors may be tested and determined to be good or bad. In fact, the test will help identify or categorize the semiconductor. Most transistor failures are catastrophic. The curve tracer will immediately show such failure. It will also immediately identify a good transistor of unknown type as NPN or PNP. The normal operating current range can be rapidly determined and, with experience or reference data, the device can be categorized.

Application of the Curve Tracer

TESTING BIPOLAR TRANSISTORS

The most common application of the semiconductor curve tracer is the testing of NPN and PNP junction transistors made of either germanium or silicon. The instrument will accurately measure several parameters of such transistors under dynamic conditions. Range adjustments allow measurements from the smallest signal transistor to high current power transistors. An extensive list of parameters include:

Current Gain (DC and AC beta)
Collector-emitter breakdown
Base-emitter reverse breakdown
Output admittance
Saturation Voltage
Saturation Resistance
Cutoff current
Leakage current
Linearity and distortion
Effects of temperature
Identification of germanium or silicon
Matching
Sorting and substitution.

Semiconductor curve tracers can also test signed diodes, rectifying diodes, zener diodes, unijunction transistors, SCR's, triacs, tunnel diodes, diacs, and even some IC's.

Before using a semiconductor curve tracer, become familiar with the one in your lab. Read the instruction manual and make any adjustments or calibrations if necessary.

ACTIVITY SHEET

G 9.2

SEMICONDUCTOR TESTERS

TRUE/FALSE

1. Generally, semiconductor testers can be placed in- or out of-the circuit.

2. Semiconductor testers can determine if a semiconductor is PNP or NPN and if it is made of silicon or germanium.

3. A semiconductor curve tracer uses an oscilloscope to display its information.

4. Germanium transistors are usually packaged in plastic.

5. All transistors will have some gain with the collector and emitter leads interchanged, except Darlingtons.

6. Before using a curve tracer, you should read the instruction manual.

7. The user should become familiar with abnormal results obtained by testing semiconductors immediately.

8. A common application of a curve tracer may be to measure leakage current of a transistor.

9. A curve tracer can check some IC's.

10. Power transistors come in either TO-5 or TO-3 packages.

ACTIVITY SHEET ANSWER KEY

G 9.2

1. T
2. T
3. T
4. F
5. T
6. T
7. F
8. T
9. T
10. T

PROGRAM: ELECTRONICS

TASK: Set up and operate semiconductor testers and curve tracers.

TASK #: G 9.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ___________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ___________

OBJECTIVE:

Set up and operate semiconductor testers and curve tracers.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation contact your instructor. You must score at least 80 out of 100 points, or achieve a score equivalent of 80%, for mastery.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must score 80 out of 100 points, or achieve a score equivalent of 80%, for mastery.

ELECTRONICS

SEMICONDUCTOR TESTERS

G 9.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
1.	Was the circuit wired according to the schematic?	Y	N
2.	Does the circuit function properly?	Y	N
3.	Was necessary data recorded?	Y	N
4.	Was the correct equipment used?	Y	N
5.	Was the equipment used correctly?	Y	N
6.	Were safety precautions followed?	Y	N
7.	Was the equipment returned to proper storage area?	Y	N

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

SCORE ______

EXAM G 9.4

DIRECTIONS: Complete the table below using the semiconductor tester as specified in the operating manual(s). If the gain measures within its stated tolerance, it is good; if not, it is bad. If the diode's currents test within tolerance, it is good. This is a timed test; you have ten (10) minutes for completion.

SEMICONDUCTOR TESTER

ITEM AND NUMBER		RATED VALUE	MEASURED VALUE	GOOD/BAD
PNP	1			
	2			
	3			
NPN	1			
	2			
	3			
DIODES	1			
	2			
	3			

INSTRUCTOR'S NOTE: The items tested and the type of tester used requires that you complete the answer sheet using the numbered items and the tester.

EXAM KEY G 9.4 CONT'D.

CURVE TRACER

DIRECTIONS: Obtain the operators manual for your curve tracer, and read the procedure for testing a diode, bipolar transistor, and unijunction transistor. Obtain one each of the above devices. Generate the curve(s) for each device. Draw the results on a sheet of graph paper. This is a timed test; you have thirty (30) minutes for completion.

ITEM AND NUMBER		RATED VALUE	MEASURED VALUE	GOOD/BAD
PNP	1			
	2			
	3			
NPN	1			
	2			
	3			
DIODES	1			
	2			
	3			

INSTRUCTOR'S NOTE: The items tested and the type of curve tracer used requires that you complete the answer sheet using the numbered items and the curve tracer.

ELECTRONICS

PERFORMING LAB PRACTICES

G 10: CONNECTORS AND THEIR USES

TASK:	Identify types of connectors and their uses.
PURPOSE:	As the electronic field continues to grow, so has the use of connectors. More and more special applications and types of connectors are being created. It is essential that you have a knowledge of these basic connectors and their uses.
OBJECTIVE:	Given the necessary resources and various connectors, you will identify them by name and application. You will score at least 80% on a written exam and laboratory performance.

ESTIMATED CLASS TIME: 3 HOURS

LABORATORY PRACTICES

LEARNING STEPS

G 10: CONNECTORS AND THEIR USES

READ: Information Sheet G 10.1, "Connectors and Their Uses."

READ: Information on identifying types of connectors and their uses from resources available in your school. Contact your instructor.

COMPLETE: Activity Sheet G 10.2, "Connectors and Their Uses."

COMPLETE: Lab Performance on identifying types of connectors and their uses. See your instructor.

COMPLETE: Exam G 10.3. See your instructor for an assortment of connectors to identify by name and use.

RECOMMENDED EQUIPMENT

An assortment of RF and Audio Connectors

INFORMATION SHEET

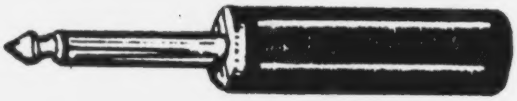
G 10.1

CONNECTORS AND THEIR USES

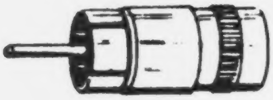
Connectors used in the electronic field can generally be classified as audio and RF; however their specific use is not restricted to these areas. For this task we will classify connectors in their general area of use.

Study these connectors until you know their name and uses. It would be impossible to list all areas in which these connectors can be used. Remember there are many other uses for these connectors.

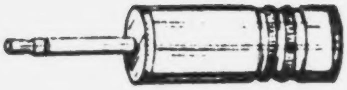
Standard Phone Plug-2 Conductor
Audio



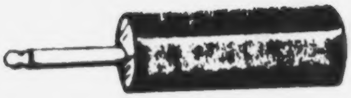
Mini Phone Plug
Audio



Sub-mini Phone Plug
Audio

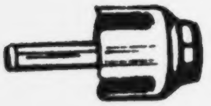


Shielded RCA Pin Plug
Audio

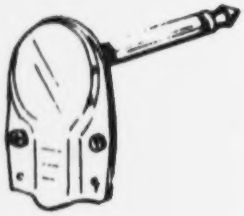


INFORMATION SHEET G 10.1 CONT'D.

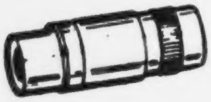
RCA Pin Plug
Audio



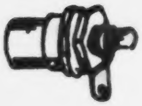
Right Angle Phone Plug
Audio



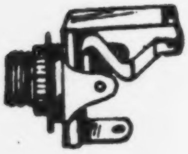
RCA Type In-Line Jack
Audio



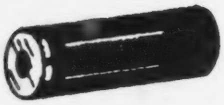
RCA Type Pin Jack
Audio



Mini-type Jacks-Chassis Mount
Audio

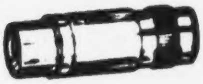


Mini-type Jacks - In-Line
Audio

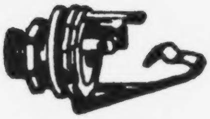


INFORMATION SHEET G 10.1 CONT'D.

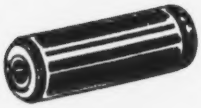
Shielded Mini-type Jacks
Audio



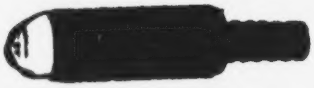
Standard Phone Jack - 2 Conductor
Audio



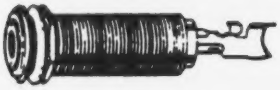
Standard Phone Jack - In-line
Audio



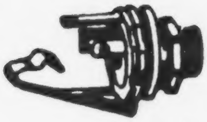
3-Conductor Mini Jack - In-line
Audio



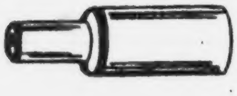
3-Conductor Mini Jack - Chassis Mount
Audio



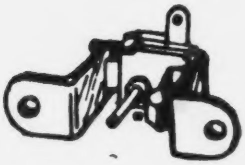
Standard Phone Jack - 3 Conductor
Chassis Mount
Audio



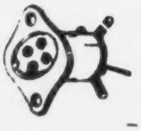
DC Power Plug
Power



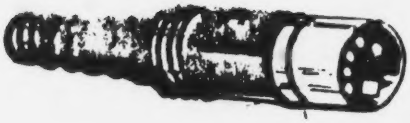
DC Power Jack
Power



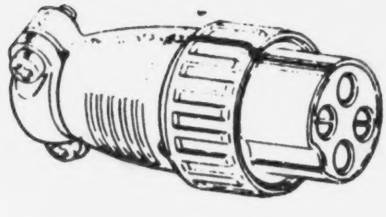
Din Type Jack - Chassis Mount
Audio/Power



Din Type Plug
Audio/Power



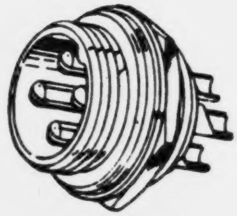
CB Type Connector
Audio



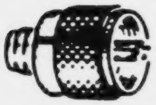
1884

INFORMATION SHEET G 10.1 CONT'D.

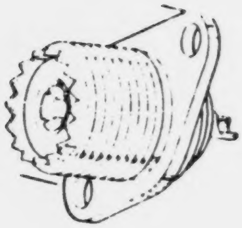
CB Type Connector - Chassis Mount
Audio



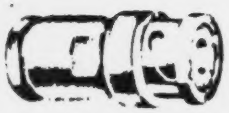
PL-259 Type
RF



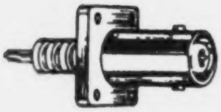
PL-258 Type
RF



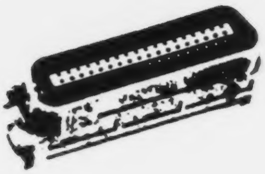
BNC Type Plug
RF



BNC Type Jack- Chassis Mount
RF

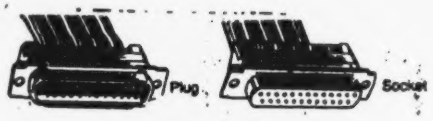


Ribbon Type Chassis
Computer

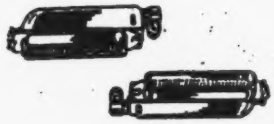


INFORMATION SHEET G 10.1 CONT'D.

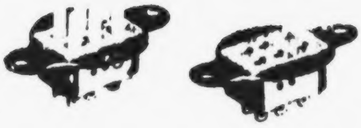
Ribbon Type Cord
Computer



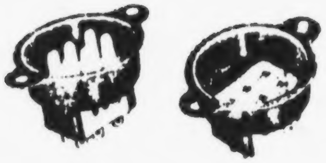
Ribbon Type Cord
Computer



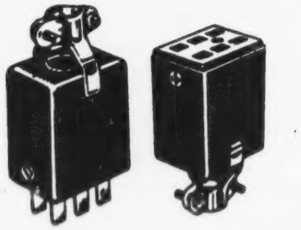
Jones Type Chassis Mount-Flush Plate
Audio/Power



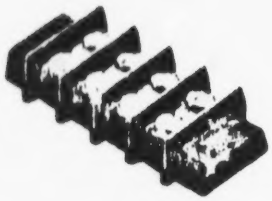
Jones Type Chassis Mount-Recessed Plate
Audio/Power



Jones Type Cable Mount
Audio/Power



Barries Terminal Strips
Power/Control



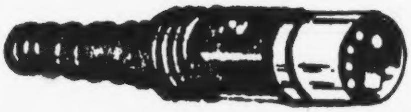
ACTIVITY SHEET

G 10.2

CONNECTORS AND THEIR USES

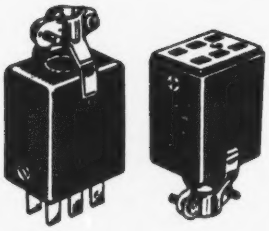
1. NAME ____________________

USE ____________________



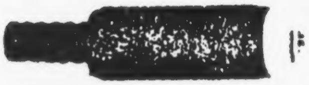
2. NAME ____________________

USE ____________________



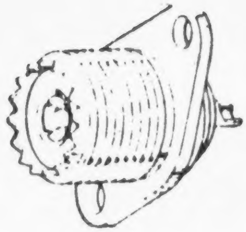
3. NAME ____________________

USE ____________________



4. NAME ____________________

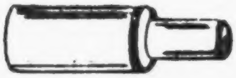
USE ____________________



ACTIVITY SHEET G 10.2 CONT'D.

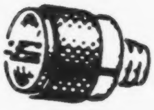
5. NAME ______________________

USE ______________________



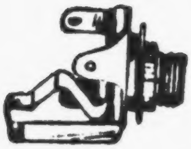
6. NAME ______________________

USE ______________________



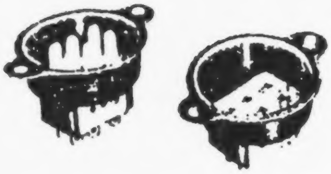
7. NAME ______________________

USE ______________________



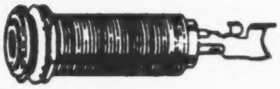
8. NAME ______________________

USE ______________________



9. NAME ______________________

USE ______________________

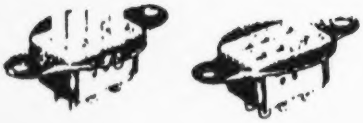


1888

ACTIVITY SHEET G 10.2 CONT'D.

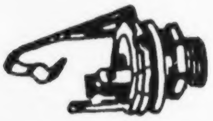
10. NAME ____________________

USE ____________________



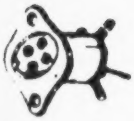
11. NAME ____________________

USE ____________________



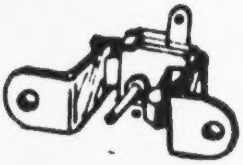
12. NAME ____________________

USE ____________________



13. NAME ____________________

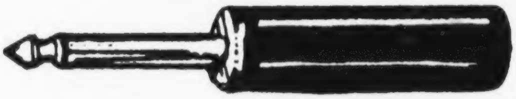
USE ____________________



ACTIVITY SHEET G 10.2 CONT'D.

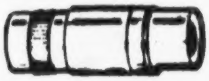
14. NAME ______________________________

USE ______________________________



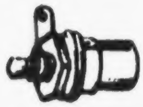
15. NAME ______________________________

USE ______________________________



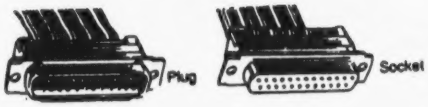
16. NAME ______________________________

USE ______________________________



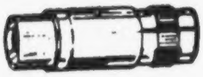
17. NAME ______________________________

USE ______________________________


Plug
Socket

18. NAME ______________________________

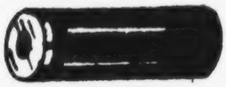
USE ______________________________



ACTIVITY SHEET G 10.2 CONT'D.

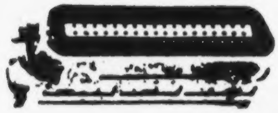
19. NAME ______________________________

USE ________________________________



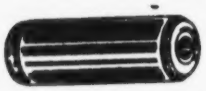
20. NAME ______________________________

USE ________________________________



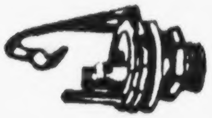
21. NAME ______________________________

USE ________________________________



22. NAME ______________________________

USE ________________________________



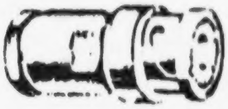
23. NAME ______________________________

USE ________________________________

ACTIVITY SHEET G 10.2 CONT'D.

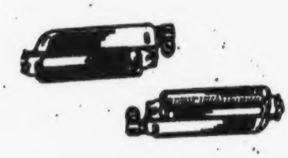
24. NAME ____________________

USE ____________________



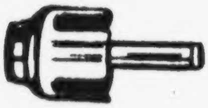
25. NAME ____________________

USE ____________________



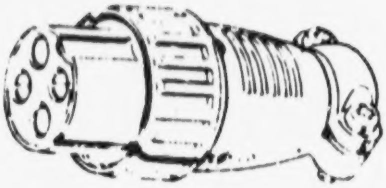
26. NAME ____________________

USE ____________________



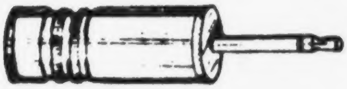
27. NAME ____________________

USE ____________________



28. NAME ____________________

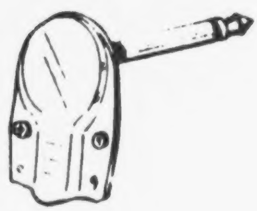
USE ____________________



ACTIVITY SHEET G 10.2 CONT'D.

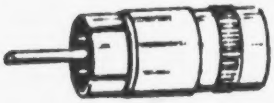
29. NAME ________________________

USE ________________________



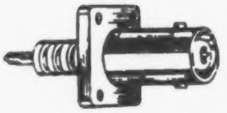
30. NAME ________________________

USE ________________________



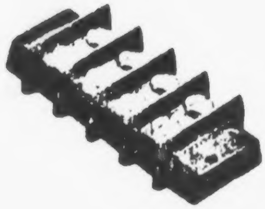
31. NAME ________________________

USE ________________________



32. NAME ________________________

USE ________________________



33. NAME ________________________

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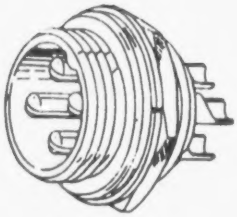


ACTIVITY SHEET KEY G 10.2

1. DIN TYPE PLUG, AUDIO/POWER
2. JONES TYPE CABLE MOUNT, AUDIO/POWER
3. 3-CONDUCTOR MINI JACK IN-LINE, AUDIO
4. PL-258 TYPE, RF
5. POWER PLUG, POWER
6. PL-259 TYPE, RF
7. MINI-TYPE JACK CHASSIS MOUNT, AUDIO
8. JONES TYPE CHASSIS MOUNT-RECESSED PLATE, AUDIO/POWER
9. THREE CONDUCTOR MINI JACK-CHASSIS MOUNT, AUDIO
10. JONES TYPE CHASSIS MOUNT-FLUSH PLATE, AUDIO/POWER
11. STANDARD PHONE JACK 2 CONDUCTOR, AUDIO
12. DIN TYPE JACK CHASSIS MOUNT, AUDIO/POWER
13. DC POWER JACK, POWER
14. STANDARD PHONE PLUG 2 CONDUCTOR, AUDIO
15. RCA TYPE IN-LINE JACK, AUDIO
16. RCA TYPE PIN JACK, AUDIO
17. RIBBON TYPE CORD, COMPUTER
18. SHIELDED MINI-TYPE JACK, AUDIO
19. MINI-TYPE JACK IN-LINE, AUDIO
20. RIBBON TYPE CHASSIS MOUNT, COMPUTER
21. STANDARD PHONE JACK IN-LINE, AUDIO
22. STANDARD PHONE JACK 2 CONDUCTOR, AUDIO
23. MINI PHONE PLUG, AUDIO
24. BNC TYPE PLUG, RF
25. RIBBON TYPE IN-LINE, COMPUTER
26. RCA PIN PLUG, AUDIO
27. CB TYPE CONNECTOR, AUDIO
28. SUB-MINI PHONE PLUG, AUDIO
29. RIGHT ANGLE PHONE PLUG, AUDIO
30. SHIELDED RCA PIN PLUG, AUDIO
31. BNC CHASSIS MOUNT, RF
32. BARRIER TERMINAL STRIP, POWER/CONTROL
33. CB TYPE CONNECTOR CHASSIS MOUNT, AUDIO

ELECTRONICS

RECORDING AND REPORTING TECHNICAL MATERIAL

H 1: RECORD DATA AND DESIGN CURVES AND GRAPHS

TASK: Record data design curves and graphs.

PURPOSE: As a student and, later, as an employee you will perform many tasks that will require the recording of various types of data. It is very important that you know how to record this data in a clear and concise manner. In this task you will learn to record and display data in the form of curves, charts and graphs.

OBJECTIVE: Given the necessary information and resources, you will record a minimum of one graph, one chart and one set of design curves.

ESTIMATED CLASS TIME: 1 HOUR

RECORDING AND REPORTING TECHNICAL MATERIAL

LEARNING STEPS

H 1

READ:	Information Sheet H 1.1, "Recording Data by the Use of Graphs, Charts and Curves."
READ:	Information on recording data by the use of graphs, charts and curves from resources available in your school. See you instructor.
COMPLETE:	Activity Sheet H 1.2.
COMPLETE:	To complete the Exam for this task you will need to record one graph, one chart and one set of curves. This means this task will be assigned to you at a time when it becomes a part of an actual lab performance.

INFORMATION SHEET

H 1.1

RECORDING DATA BY THE USE OF GRAPHS, CHARTS AND CURVES

Recording data in graphs, charts, and curves turns information into a picture which can often be understood more easily than the original data.

For example, we have a record of the number of students present in a classroom on the first day of five different months. On September 1st, 24 pupils were present; on the first of October, 36; on the first of November, 32. On December 1st, 38; and on January 1st, 34.

Figure H 1.1-1 represents the data in a line graph. Line graphs are made by drawing lines at right angles to each other. One of the lines is used to show the number of pupils present; the other, dates. Points on the drawing indicate how many pupils were present on each date listed. These points are then connected by a line. This type of graph can be used for many kinds of facts such as the grades a pupil makes on certain days, or the amount of production of factories or farms at a given time. It can also be used to indicate the output of amplifiers under certain conditions.

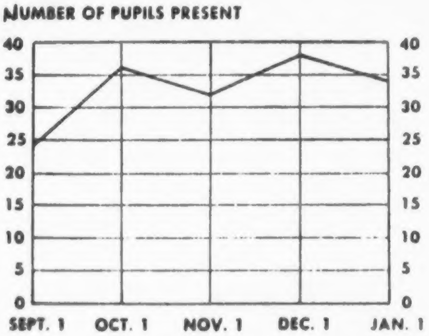


Figure H 1.1-1

Figure H 1.1-2 represents the date in a horizontal bar graph. Such a graph can be used to illustrate the same kind of facts as the line graph. The bar graph is a good way of comparing increases and decreases in quantity over a period of time.

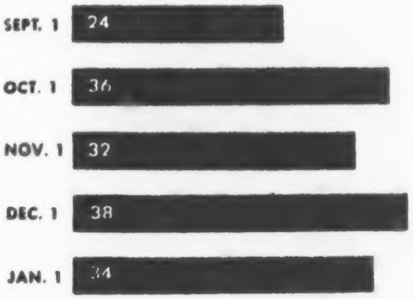


Figure H 1.1-2

INFORMATION SHEET H 1.1 CONT'D.

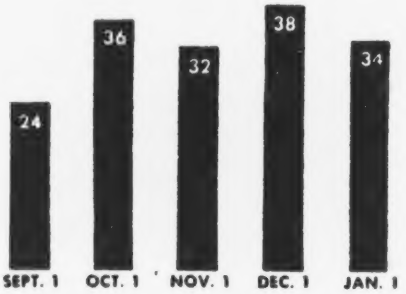
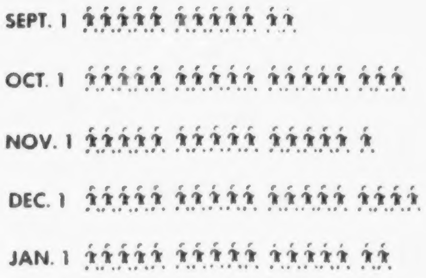


Figure H 1.1-3

Figure H 1.1-3 is a bar graph, but in this case it is a vertical bar graph.



Each symbol represents 2 pupils present

Figure H 1.1-4

The picture graph uses symbols instead of lines or bars to make its point. The pictorial form makes it easier for the reader to grasp the idea represented. It is most often used in newspapers and magazines to convey information to casual readers who have not the time to examine lists of figures. This type of graph originated in the pictographs used by primitive people. Figure H 1.1-4 illustrates the pictograph.

INFORMATION SHEET H 1.1 CONT'D.

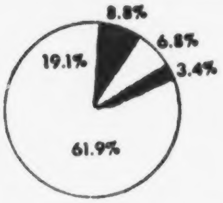


Figure H 1.1-5

The circle graph, shown in Figure H 1.1-5, shows the relation of the parts of anything to the whole. This graph represents the Income of an Electronics Firm. The sum is divided as follows: Wages, 61.9 per cent; Raw materials, 19.1 per cent; Utilities, 8.8 per cent, Advertising, 3.4 per cent and Profit, 6.8 per cent. These percentages may appear as wedges such as pieces of pie. For this reason, these graphs are often referred to as "pie charts".

Another form of graph used in electronics today is called the characteristic curve graph, often referred to as a set of "characteristic curves." Figure H 1.1-6 shows a set of characteristic curves for a common emitter transistor circuit. The graph indicates that for a constant value of base current (I_b), collector current (I_c) remains relatively constant. Notice that changes in collector-emitter voltage (E_{ce}) have little effect upon collector current. Notice this family of curves is based upon six different values of base current. The characteristic curve graph is used to illustrate the various operating parameters of components used in electronics.

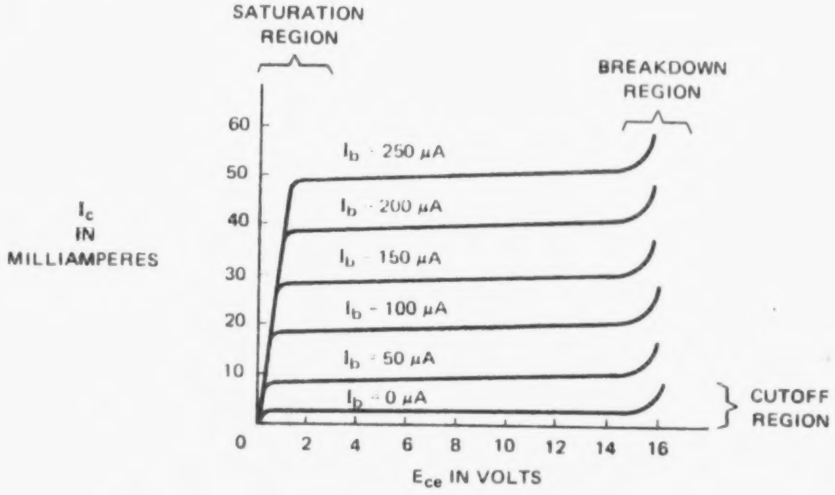


Figure H 1.1-6

INFORMATION SHEET H 1.1 CONT'D.

Another method of recording data is the use of the chart. A "chart" is simply a sheet giving information in the form of a table. From your previous studies, you should be familiar with the chart and its use.

ACTIVITY SHEET

H 1.2

RECORDING DATA BY THE USE OF GRAPHS, CHARTS AND CURVES

1. By using graphs, charts or curves, you are turning data into a ______________.

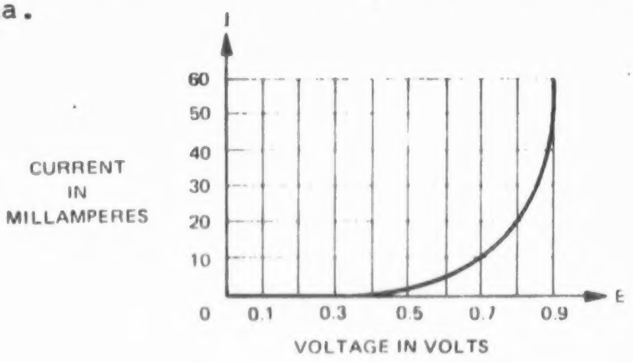
2. Line graphs are made by drawing lines at ____________ ____________ to each other.

3. The bar graph can be constructed in two ways: they are called the ____________ bar graph and the ____________ bar graph.

4. The circle graph is sometimes called the ____________ chart.

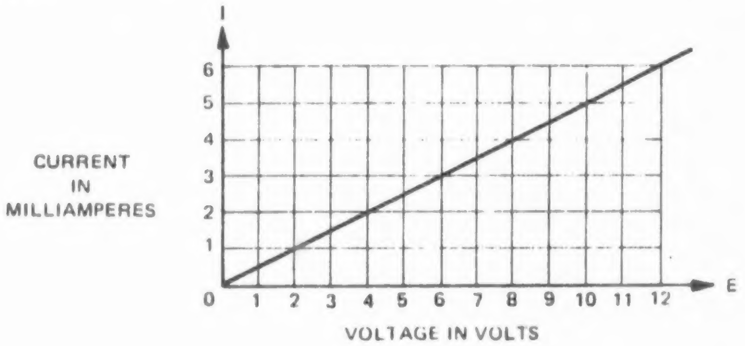
5. Referring to Figure H 1.2-1: When E equals 0.8 volt, I equals ____________ ma.

Figure H 1.2-1



6. Referring to Figure H 1.2-2: When I equals 5 ma, E equals ____________ volts.

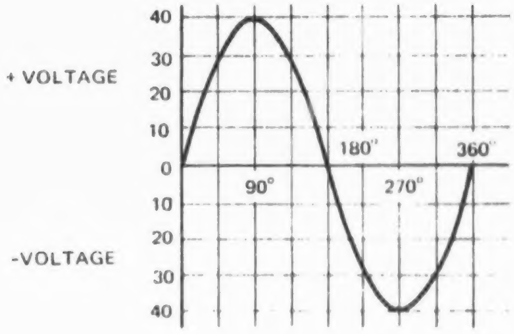
Figure H 1.2-2



7. Referring to Figure H 1.2-3: When the sine wave is at 135, the voltage will be ____________ volts.

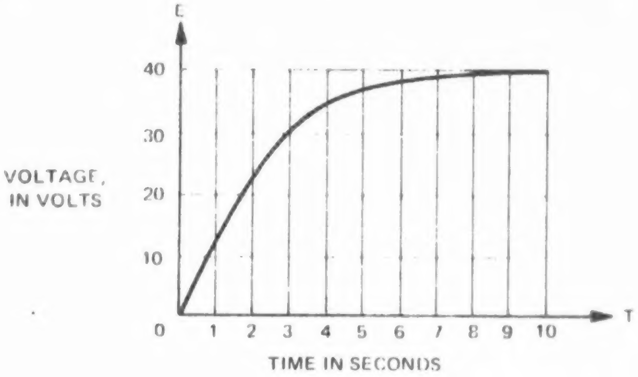
ACTIVITY SHEET H 1.2 CONT'D.

Figure H 1.2-3



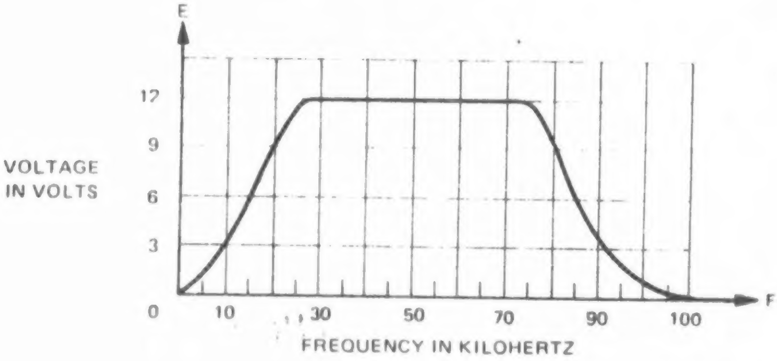
8. Referring to Figure H 1.2-4: When time is 3 seconds, the voltage will be ___________ volts.

Figure H 1.2-4



9. Referring to Figure H 1.2-5: The filter has full output between _____________ kHz and _____________ kHz.

Figure H 1.2-5



ACTIVITY SHEET H 1.2

ANSWER SHEET

1. Picture
2. Right Angle
3. Vertical, Horizontal
4. PIE
5. 20
6. 28
7. 30
8. 30
9. 26, 74

ELECTRONICS

RECORDING AND REPORTING TECHNICAL MATERIAL

H 2: WRITE REPORTS

TASK: Write reports.

PURPOSE: As a student and, later, as an employee you will write many technical reports, particularly if you become an engineer or engineering technician. The purpose of this task is to help you prepare reports that meet professional standards for form and content.

OBJECTIVE: Given the necessary information and resources, you will write at least one technical report. This report must contain all the necessary information in a clearly understandable way. You must score 10 out of 12 or 83% on a product checklist to master this task.

NOTE: The objective is limited to form and content. This is not meant to imply that grammar, style and spelling are unimportant. To go beyond form and content would require developing a long sequence of learning packages which would, in effect, amount to an English course. If you are weak in grammar, spelling, and style, you should at least obtain a good manual on technical report writing and follow its suggestions.

ESTIMATED CLASS TIME: 2 HOURS

WRITE REPORTS

LEARNING STEPS

H 2

READ:	Information Sheet H 2.1, "The Components of a Technical Report."
READ:	Information on the components of a technical report from resources available in your school. See your instructor.
COMPLETE:	Activity Sheet H 2.2.
COMPLETE:	You will need to write an actual technical report. This means this task will be assigned to you at a time when your studies require a written report.
COMPLETE:	Performance Checklist H 2.3.

INFORMATION SHEET

H 2.1

THE COMPONENTS OF A TECHNICAL REPORT

Most of us look at the task of writing a report with something less than great joy. Yet the report is a vital link in the technology which helps to support our society.

A report should communicate clearly. A report may have all the words spelled correctly and follow correct English grammar, and still be difficult to understand, unless it presents relevant material in a well-organized form.

This information sheet will present three sections of information on report writing: I. The form or outline of the report, II. The content of the report, and III. Hints on improving your report.

I. An outline of a technical report

A. A statement of the problem or objective which tells what you plan to prove, demonstrate, or learn from the experiment.

B. Background information which briefly "sets the stage" for the experiment. This may be optional on some reports.

C. The procedure, which includes enough information to allow the reader to understand what you did in the experiment.

D. Observations or data in whatever form is clearest for the reader. This may also include calculations and formulas used.

E. Discussions and/or conclusions which refer to the statement.

II. The content of a technical report

A. Problem: This should clearly state what you are writing about in the first few sentences. Here is an example:

INFORMATION SHEET H 2.1 CONT'D.

It is known that changes in temperature have a great effect on transistors. This report describes the changes in the parameters of a transistor amplifier under various temperature conditions.

You must always keep in mind the audience which you are trying to reach. Try to use the appropriate vocabulary. You should also adjust the content of your report to what your audience wants to know. A technical audience may want all the fine details while a supervisor may want only an outline of the results.

B. Background Information: This includes the history of previous studies and a general discussion of how this work relates to the field of technology you are working in. You will often have trouble deciding how much to include here. Generally, by keeping the needs of the reader in mind, you can include sufficient information without becoming too wordy. If a reader needs to know something to understand the report, include it; if not, leave it out.

C. Procedure: This part of you report contains several sections:

1. A list of equipment and parts used. For special equipment, list the manufacturer and model number.
2. A sketch, schematic, or diagram of the experimental arrangement.
3. The steps which you followed in the experiment.

Again, keep your reader in mind. Your instructor will probably be interested in knowing how clearly you are able to describe the experiment. This means you must include the essential points without getting wordy.

D. Observations and Data: Most of your data or readings will be in the form of tables. While this may be clear enough for a small number of readings, large numbers will probably require a graph.

Where calculations are necessary to process the data, show a sample set of calculations. This must include the formulas and units involved. Be sure that these calculations are neatly done with all terms labeled or defined.

INFORMATION SHEET H 2.1 CONT'D.

In some cases you will need to comment on probable errors or discrepancies. The calculation of probable error can be complex, but you should be able to give some indication of the error in your results. Discrepancies are "wild" readings which do not seem to agree with the rest of the data. Try to explain how these occurred.

E. Discussions and conclusions: This is the climax of your report. Try to show clearly how your results relate to the original problem. You can discuss success or failure, the errors involved, possible improvements and special difficulties encountered. Do not assume that a graph or calculation will be sufficient to allow the reader to reach the same conclusion which you reached. Be explicit and state your conclusion exactly.

III. Some hints on writing a better report

A. Don't worry about form and grammar on your first draft. Get the material written down and revise later.

B. Revise the paper and correct spelling, grammar, and form. Also consider the audience who will read the report.

C. Use abbreviations sparingly.

D. When you include several equations, number them.

E. Caption diagrams.

F. Be direct; avoid phrases like "it was apparent that"; in fact, use "it" sparingly.

G. The physical arrangement of the report is also important. Follow the style required by your instructor or employer. Common practices require that you:

1. Type reports using good paper and a fresh ribbon.
2. Use 1 inch or larger margin.
3. Number pages.
4. Double space all material.
5. Keep a carbon or xerox copy.

ACTIVITY SHEET

H 2.2

1. The first step toward a good technical report is a(an) ________________.

2. The first part of the report should be a statement of the ______________ or _____________.

3. The last part of the report should be ______________ and/or _________________ .

4. Who must you keep in mind when writing a report?

5. If calculations are involved in a report, is it necessary to show them in detail?

6. In your first draft of the report, should you be concerned about grammar or form?

7. If diagrams are used, should they be labeled?

ACTIVITY SHEET H 2.2

ANSWER SHEET

1. Outline
2. Problem, Objective
3. Discussion, Conclusion
4. Those who will read the report.
5. Yes
6. No
7. Yes

PROGRAM: ELECTRONICS

TASK: RECORDING AND REPORTING TECHNICAL MATERIAL

TASK # H 2.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ____________

TERMINAL PERFORMANCE OBJECTIVE:

WRITE REPORTS

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 30 minutes and must score at least 10 out of 12 points or 83% for mastery.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 30 minutes and must score 10 out of 12 points or 83%.

ELECTRONICS

RECORDING AND REPORTING TECHNICAL MATERIAL

H 2.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
1.	Was correct grammar used?	Y	N
2.	Was correct style used	Y	N
3.	Are all words spelled correctly?	Y	N
4.	Is the report:		
	Clear?	Y	N
	Easy to understand?	Y	N
	Logically organized?	Y	N
5.	Does the report include:		
	An outline?	Y	N
	A statement of the problem or objective?	Y	N
	Necessary background information?	Y	N
	The experimental procedure?	Y	N
	Necessary observations or data?	Y	N
	Discussions and/or conclusions?	Y	N

TOTAL POINTS POSSIBLE 12

POINTS NEEDED FOR MASTERY 10

SCORE ______

ELECTRONICS

RECORDING AND REPORTING TECHNICAL MATERIAL

H 3: MAKE EQUIPMENT FAILURE REPORTS

TASK:	Make equipment failure reports.
PURPOSE:	The writing of equipment failure reports is an extremely vital part of many jobs in electronics. In this task you will learn the proper form and content for equipment failure reports.
OBJECTIVE:	Given the necessary information on at least one equipment failure, you will complete the report in such a manner that no information is missing and the failure is clearly defined.
NOTE:	The grammar and spelling problems which you may have are beyond the scope of a single learning guide. You should obtain a good reference book on this subject for further suggestions and help. See your instructor.

ESTIMATED CLASS TIME: 2 HOURS

MAKE EQUIPMENT FAILURE REPORTS

LEARNING STEPS

H 3

READ: Information Sheet H 3.1, "The Components of an Equipment Failure Report."

READ: Information on the components of an equipment failure report from resources available in your school. See your instructor.

COMPLETE: Activity Sheet H 3.2

COMPLETE: An actual equipment failure report provided by your instructor.

INFORMATION SHEET

H 3.1

THE COMPONENTS OF AN EQUIPMENT FAILURE REPORT

This information sheet will present three sections of information on writing equipment failure reports.

1. An outline of an equipment failure report

   A. A statement of the make, model, and serial number of the unit that failed.

   B. Background information on the operating conditions of the unit that failed, giving a detailed listing of the operating data.

   C. The procedure and task the unit was being used for.

   D. The procedure you used in repairing the unit.

   E. Observations and/or data from other equipment used in conjunction with the failed unit.

2. The content of an equipment failure report

   Problem: This should clearly state the unit name and a description of the failure (blown fuse, operating temperature too high, wrong readings, etc.). These must be covered in the first few sentences.

   Background Information: If it has failed before, give dates and times and any procedure taken at that time to prevent recurrence.

   Procedure Used to Repair the Unit: This would include schematics or partial schematics of the unit, with the manufacturer's list of those parts within the area of the failure. Indicate which part(s) you replaced, giving a complete description of the replacement parts. Then indicate if this put the unit in working condition. If not, what other parts were required to put it in working condition. Indicate how long it was tested under operating conditions before being put back in service.

   Observations and Data: At this point, you should state your observations of the failed equipment and any other equipment used in conjunction with it. This would include your recommendations of any change(s) to be made in this operation. If you make recommendations for a change, you must be specific. Include make and model of any change of equipment, including complete information on any part changes you recommend. Next, you must be very specific as to why these changes should be made.

3. Hints on Writing a Better Report

   A. In the first draft of the report, make sure that all of the data is correct.

   B. Revise the report next, correcting all grammar and spelling.

   C. Use abbreviations sparingly.

   D. Caption diagrams.

   E. Be direct; avoid phrases like "It was apparent that...." In fact, use the word "it" sparingly.

   F. You must keep in mind the audience you are trying to reach. Who will read the report? If the reader needs to know something to understand the report, include it; if not, leave it out.

   G. Your instructor or employer may use forms for making equipment failure reports. If so, the guide lines in this learning guide should be followed.

ACTIVITY SHEET

H 3.2

THE COMPONENTS OF AN EQUIPMENT FAILURE REPORT

1. The first part of the equipment failure report should be a statement of the ______________________.

2. The second part of the equipment failure report would include the ____________________ information on the failed unit.

3. The last part of the equipment failure report will be where you list your ____________________ and/or ________________ .

4. Once you repair a piece of equipment, should it be tested under working conditions before being put in service?

5. Should you list every part used in repairing the equipment?

6. Who must you keep in mind when making an equipment failure report?

ELECTRONICS

RECORDING AND REPORTING TECHNICAL MATERIAL

H 4: SPECIFY AND REQUISITION SPECIFIC ELECTRONIC COMPONENTS

TASK:	Specify and requisition electronic components.
PURPOSE:	As a technician, you must know how to specify and requisition electronic parts. In this task you will learn how to prepare an accurate requisition for a designated electronic part.
OBJECTIVE:	Given the necessary information and resources, you will complete a minimum of three orders, specifying the requisition of specific electronic components. You must score at least 80% on a written exam and laboratory performance.

ESTIMATED CLASS TIME: 4 HOURS

SPECIFY AND REQUISITION SIMPLE ELECTRONIC COMPONENTS

LEARNING STEPS

H 4

READ: Information Sheet H 4.1, "Forms Used in the Requisition of Electronic Components."

READ: Information on forms used in the requisition of electronic components in texts found in Business Education, Distributive Education, or Marketing.

COMPLETE: Activity Sheet H 4.2.

COMPLETE: Exam H 4.3.

INFORMATION SHEET

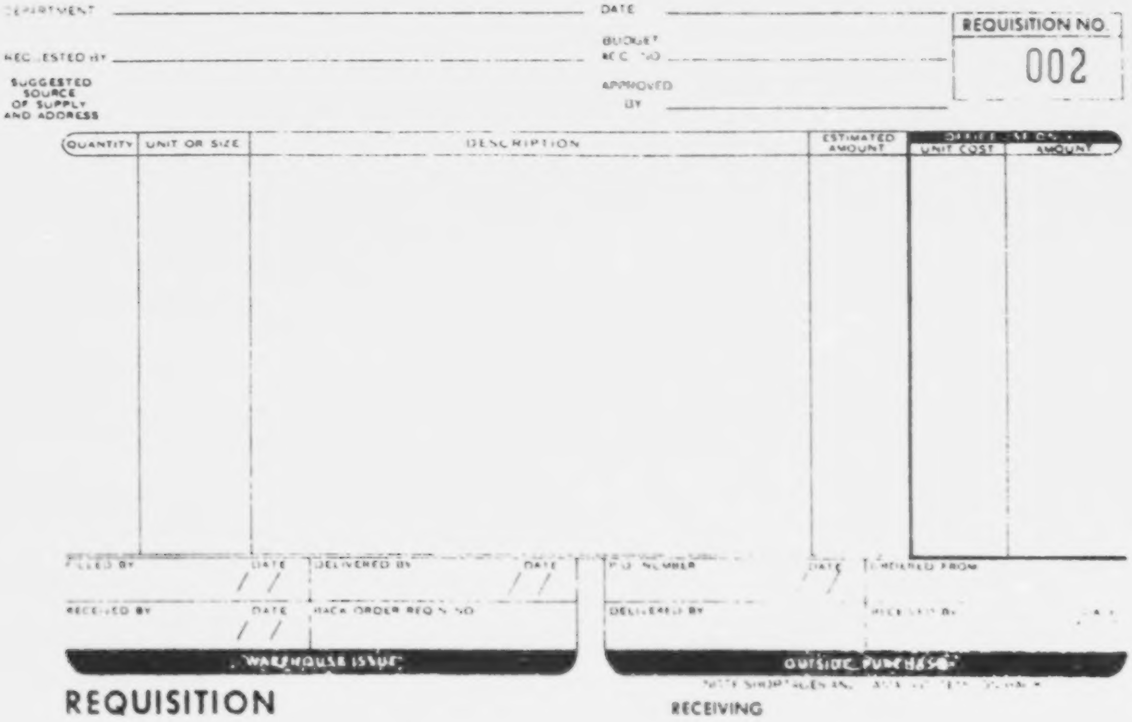
H 4.1

FORMS USED IN THE REQUISITION OF ELECTRONIC COMPONENTS

Several forms are used in the requisition of electronic components. Those used will vary with different firms. If the firm is a larger one with a central office doing the actual purchasing, usually a requisition form is required. See Figure H 4.1-1 for a sample. As you can see, this is a multiple form, with copies going to other offices. This form must specify completely what is to be purchased. This means:

1. The name of the item(s)
2. The specification of the item such as size, color, resistance, wattage, working voltage, inductance, etc.
3. The manufacturer of the part and type number
4. The vendor or source of the parts
5. The quantity wanted
6. The unit price per item
7. The total price
8. Account, department, and person to be charged
9. Date
10. Authorization - signature of the person authorized to approve purchases.

INFORMATION SHEET H 4.1 CONT'D.



DEPARTMENT
DATE
REQUISITION NO.
002
REQUESTED BY
BUDGET ACC. NO.
SUGGESTED SOURCE OF SUPPLY AND ADDRESS
APPROVED BY

QUANTITY	UNIT OR SIZE	DESCRIPTION	ESTIMATED AMOUNT	OFFICE USE ONLY UNIT COST	 AMOUNT

FILLED BY
DATE / /
DELIVERED BY
DATE / /
RECEIVED BY
DATE / /
BACK ORDER REQ'N NO.
WAREHOUSE ISSUE

P.O. NUMBER
DATE / /
ORDERED FROM
DELIVERED BY
RECEIVED BY
OUTSIDE PURCHASE

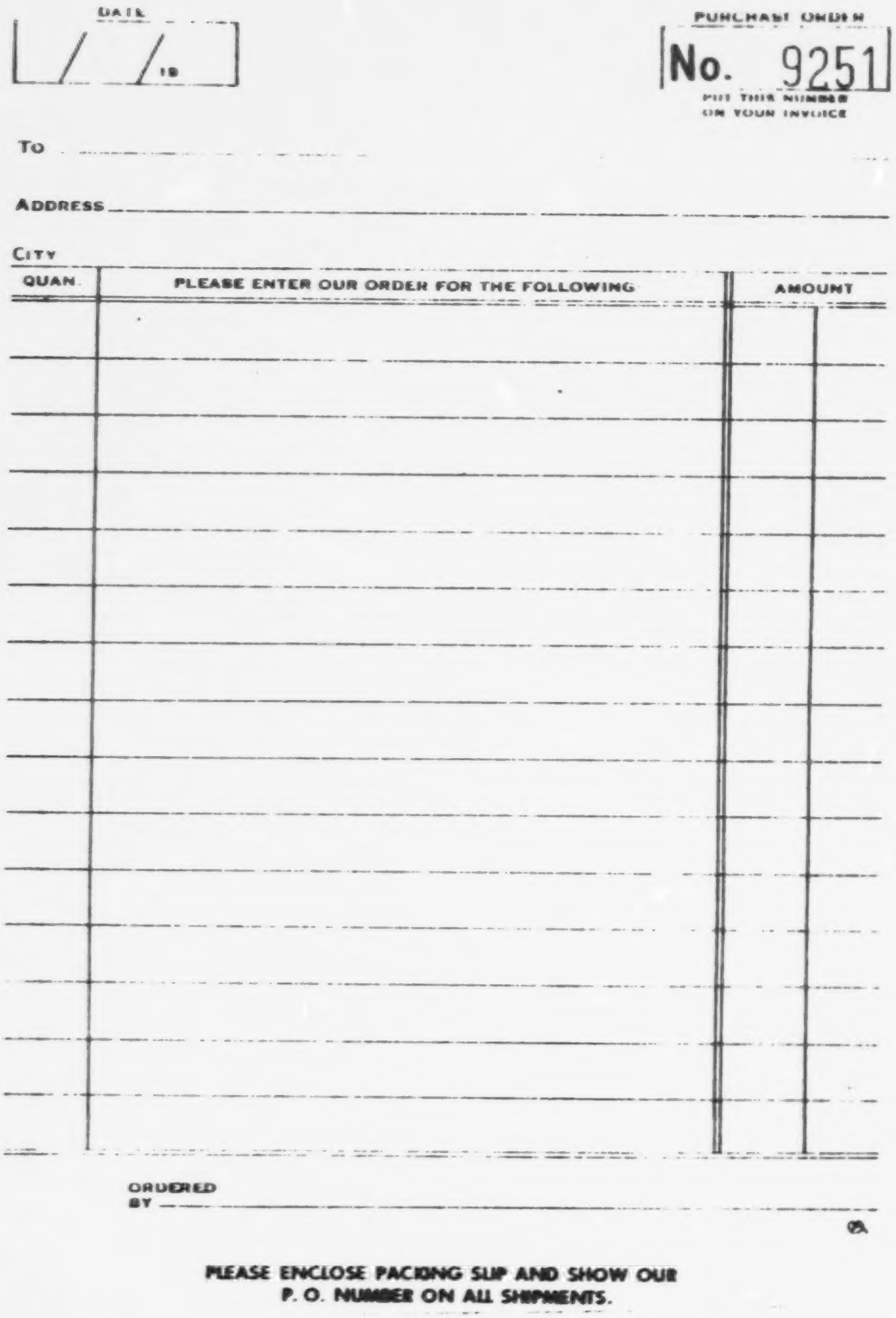
REQUISITION

RECEIVING

Figure H 4.1-1

The purchase order (P.O.) is sent or carried to the vendor; it tells the vendor to send the items listed and bill the firm. A sample P.O. is shown in Figure H 4.1-2 and H 4.1-3. Again, there are multiple copies, with copies going to other offices. The P.O. must contain the same information as the requisition.

INFORMATION SHEET H 4.1 CONT'D.



DATE

/ / 19

PURCHASE ORDER

No. 9251

PUT THIS NUMBER ON YOUR INVOICE

To

Address

City

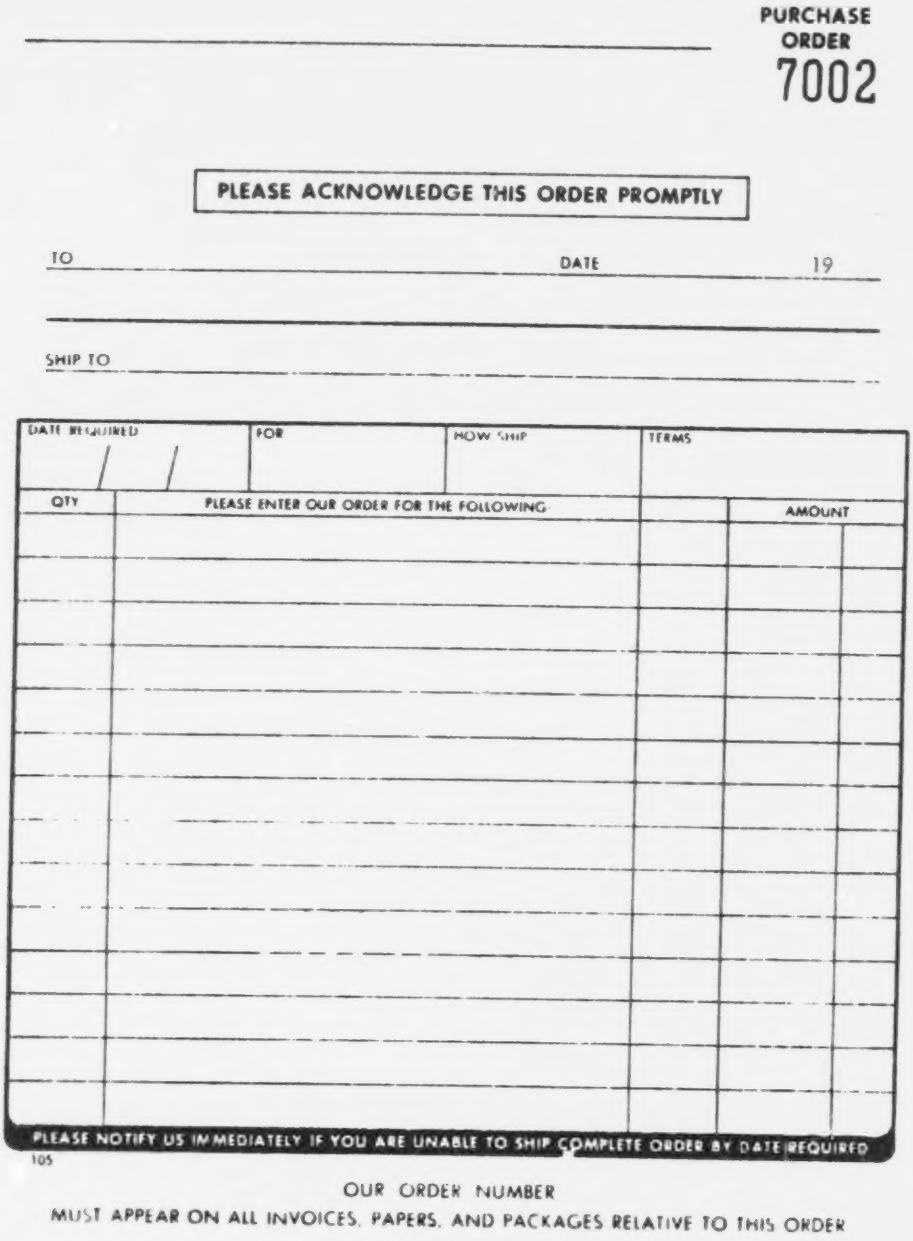
QUAN.	PLEASE ENTER OUR ORDER FOR THE FOLLOWING	AMOUNT

ORDERED BY

PLEASE ENCLOSE PACKING SLIP AND SHOW OUR P. O. NUMBER ON ALL SHIPMENTS.

Figure H 4.1-2

INFORMATION SHEET H 4.1 CONT'D.



PURCHASE ORDER
7002

PLEASE ACKNOWLEDGE THIS ORDER PROMPTLY

TO ______________________ DATE ______________ 19 ____

SHIP TO ______________________

DATE REQUIRED	FOR	HOW SHIP	TERMS
/ /			

QTY	PLEASE ENTER OUR ORDER FOR THE FOLLOWING		AMOUNT	

PLEASE NOTIFY US IMMEDIATELY IF YOU ARE UNABLE TO SHIP COMPLETE ORDER BY DATE REQUIRED

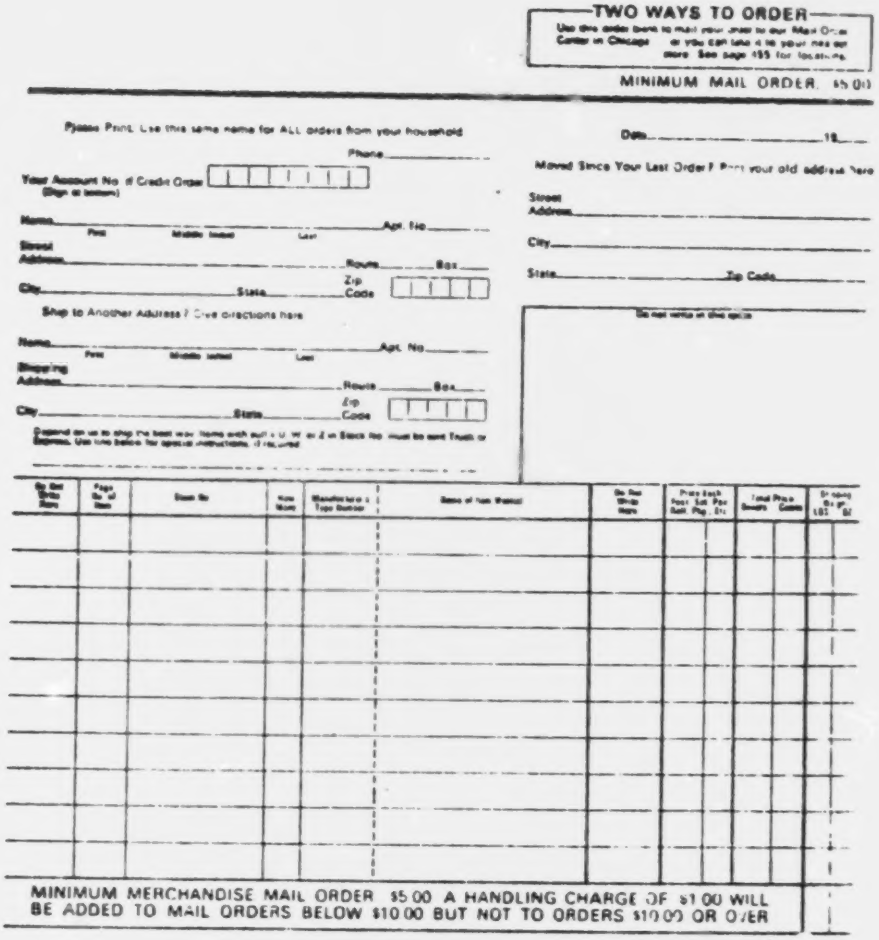
105

OUR ORDER NUMBER
MUST APPEAR ON ALL INVOICES, PAPERS, AND PACKAGES RELATIVE TO THIS ORDER

Figure H 4.1-3

INFORMATION SHEET H 4.1 CONT'D.

Another order form used is the mail order form. This order form should contain the same information as the requisition. A sample order form is shown in Figure H 4.1-4.



TWO WAYS TO ORDER

MINIMUM MAIL ORDER $5.00

Please Print. Use this same name for ALL orders from your household

Phone

Your Account No. if Credit Order

Name ____ Apt. No.

Street Address ____ Route ____ Box

City ____ State ____ Zip Code

Ship to Another Address? Give directions here

Name ____ Apt. No.

Shipping Address ____ Route ____ Box

City ____ State ____ Zip Code

Date ____ 19

Moved Since Your Last Order? Print your old address here

Street Address

City

State ____ Zip Code

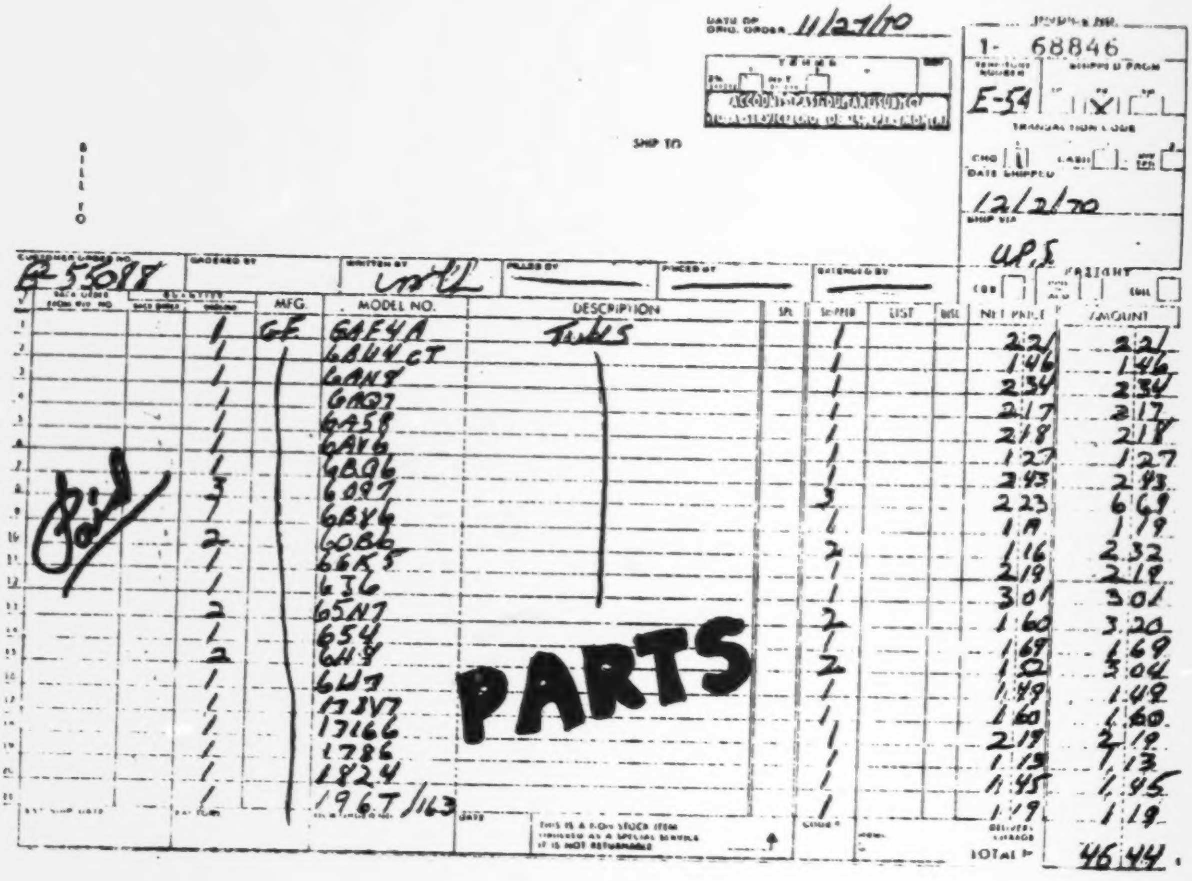
MINIMUM MERCHANDISE MAIL ORDER $5.00 A HANDLING CHARGE OF $1.00 WILL BE ADDED TO MAIL ORDERS BELOW $10.00 BUT NOT TO ORDERS $10.00 OR OVER

Figure H 4.1-4

INFORMATION SHEET H 4.1 CONT'D.

The informal order is a common way to obtain electronic parts. Parts are ordered by phone or a list is carried to the parts supplier. In either case, a purchase order should be used, for record keeping purposes.

Another form you must become familiar with is the invoice, also called a bill. A sample of this form is shown in Figure H 4.1-5. Listed on the invoice will be the items sent and prices. Items not immediately available will be back ordered (B/O).



DATE OF ORIG. ORDER 11/27/70

1- 68846

TERRITORY NUMBER E-54

DATE SHIPPED 12/2/70

SHIP VIA U.P.S.

SHIP TO

BILL TO

CUSTOMER ORDER NO. E-55088

Paid

QUANTITY ORDERED	MFG.	MODEL NO.	DESCRIPTION	SHIPPED	NET PRICE	AMOUNT
1	GE	6AE4A	Tubes	1	2.21	2.21
1		6AU4GT		1	1.46	1.46
1		6AN8		1	2.34	2.34
1		6AQ7		1	2.17	2.17
1		6AS8		1	2.18	2.18
1		6AV6		1	1.27	1.27
1		6BQ6		1	2.43	2.43
3		6097		3	2.23	6.69
1		6BY6		1	1.19	1.19
2		6OB6		2	1.16	2.32
1		6GK5		1	2.19	2.19
1		6J6		1	3.01	3.01
2		6SN7		2	1.60	3.20
1		6S4		1	1.69	1.69
2		6H8		2	1.52	3.04
1		6W7		1	1.49	1.49
1		12BV7		1	1.60	1.60
1		13166		1	2.19	2.19
1		1786		1	1.13	1.13
1		1824		1	1.45	1.45
1		196T/163		1	1.19	1.19
					TOTAL	46.44

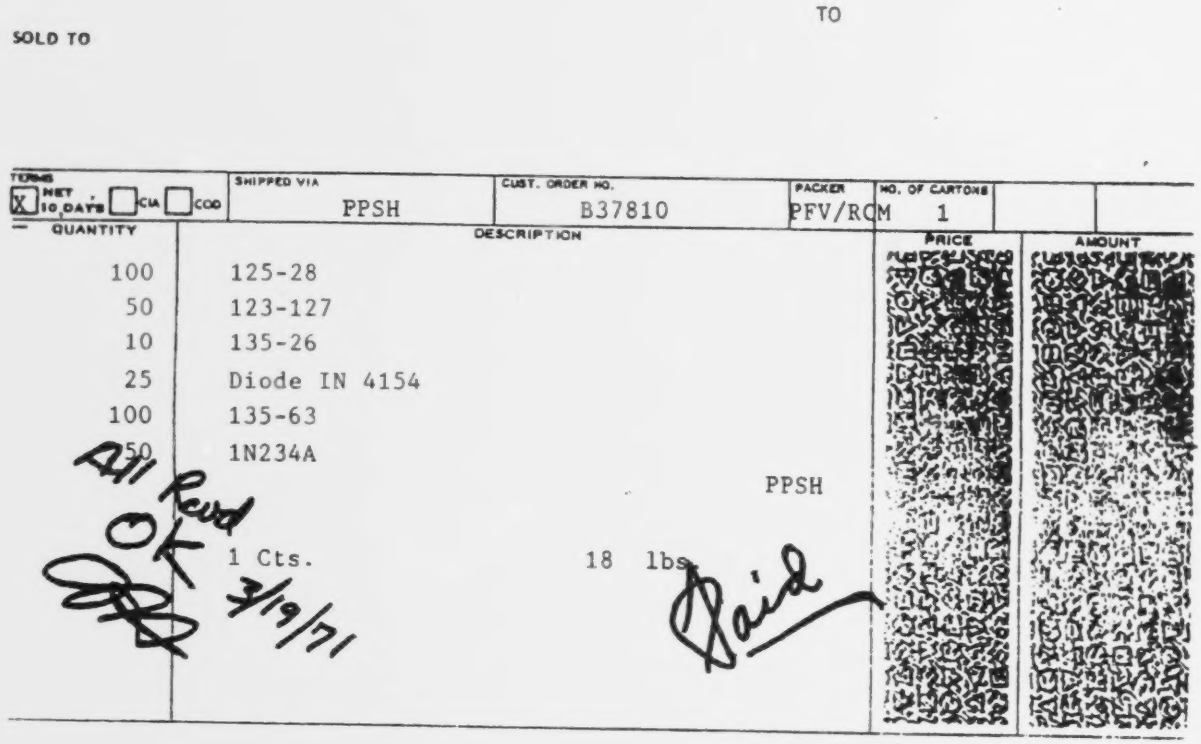
PARTS

THIS IS A NON STOCK ITEM ORDERED AS A SPECIAL SERVICE IT IS NOT RETURNABLE

Figure H 4.1-5

INFORMATION SHEET H 4.1 CONT'D.

When the parts arrive, a list of items included in the shipment will be enclosed. This is called a packing list, shown in Figure H 4.1-6. When checking a shipment, be sure to check off the items on the packing list.



SOLD TO

TO

TERMS	SHIPPED VIA	CUST. ORDER NO.	PACKER	NO. OF CARTONS
☒ NET 10 DAYS ☐ CIA ☐ COD	PPSH	B37810	PFV/RCM	1

QUANTITY	DESCRIPTION	PRICE	AMOUNT
100	125-28	[redacted]	[redacted]
50	123-127	[redacted]	[redacted]
10	135-26	[redacted]	[redacted]
25	Diode IN 4154	[redacted]	[redacted]
100	135-63	[redacted]	[redacted]
50	1N234A	[redacted]	[redacted]
	PPSH		
	1 Cts. 18 lbs.		

All Recvd OK

3/19/71

Paid

Figure H 4.1-6

ACTIVITY SHEET

H 4.2

REFER TO FIGURE H 4.2-1 FOR ALL QUESTIONS IN THIS ACTIVITY

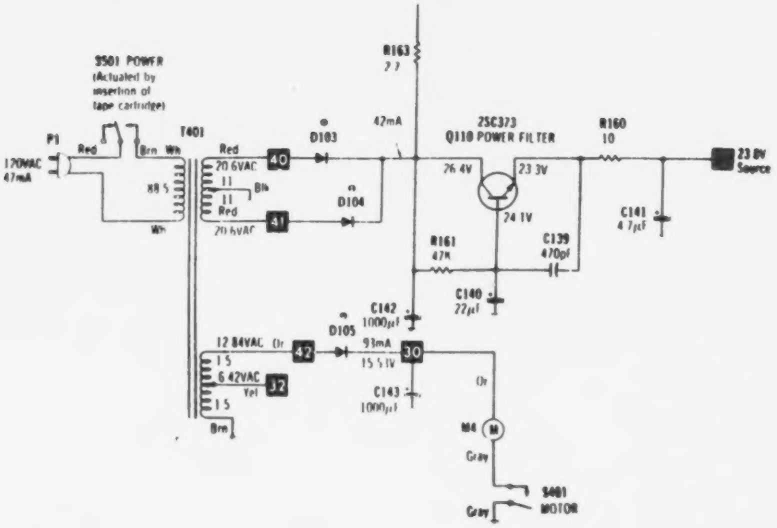

R163
2.2
S501 POWER
(Actuated by insertion of tape cartridge)
P1
120VAC
47mA
Red
Brn
Wh
T401
88.5
Red
20.6VAC
11
Blk
11
Red
20.6VAC
40
41
D103
D104
42mA
2SC373
Q110 POWER FILTER
26.4V
23.3V
24.1V
R160
10
23.8V Source
C141
4.7µF
R161
47K
C139
470pf
C140
22µf
C142
1000µf
D105
12.84VAC
Or
42
1.5
6.42VAC
Yel
32
1.5
Brn
93mA
15.51V
30
C143
1000µf
Or
M4
M
Gray
S401
MOTOR
Gray

Figure H 4.2-1

1. The following six parts must be ordered for this power supply. List all data that must be included on the requisition:

   A. D 104
   B. C 143
   C. Q 110
   D. R 160
   E. R 161
   F. D 103

ACTIVITY SHEET H 4.2

ANSWER SHEET

1. A. D104-Type, Current Rating and Voltage Rating
   B. C143-Type, Capacity, Working Voltage, Mounting
   C. Q110-Type, Manufacturer, Number or Replacement Number
   D. R160-Type, Resistance, Wattage
   E. R161-Type, Resistance, Wattage
   F. D103-Type, Voltage Rating, Wattage

SPECIFY AND REQUISITION SIMPLE ELECTRONIC COMPONENTS

EXAM

H 4.3

1. When ordering electronic parts, list at least eight items that must appear on the requisition.

Using Schematic H 4.3-1 and Parts List H 4.3-2 for the following questions:

2. Give all the necessary information for ordering:

   A. D
   B. S
   C. C
   D. C
   E. Z
   F. R

3. What is the total cost of the components listed in Question 2?

4. In Question 2, what would the total cost of the components be if 2 extra diodes were ordered?

SEE FIGURE H 4.3-2 BELOW AND FIGURE H 4.3-1 ON NEXT PAGE

Item	Stock No.	Quantity	Type No.	Item	Price Each	Total
				Plug		
				SPST Slide Switch		
				NE - 51 lamp		
1.	954-2571	1	N-471 A	Isolation Trans.	22.34	22.34
2.	1N3570 GE	4	1N3570	Diode	1.62	6.48
3.	2N1970 MOT	1	2N1970	Transistor	2.82	2.82
4.	2N2106 GE	1	2N2106	Transistor	1.97	1.97
5.	2N689 RCA	1	2N689	Transistor	9.70	9.70
6.	1N4735	1	1N4735	Zener diode 6.2 V	1.50	1.50
7.	926-1736	1	Sprague 1315	Capacitor 500 MF, 150 V	1.80	1.80
8.	926-1784	1	Sprague 1420	Capacitor 100 MF, 150 V	1.31	1.31
9.	962C2200	1	IRC	Resistor 470 ohm, 1/2 W	.07	.07
10.	962C2200	1	IRC	Resistor 180 K, 1/2 W	.07	.07
11.	961-1506	1	11-116	10 K Pot, Linear taper	2.00	2.00
12.	875C7400	1	995-5B	Resistor, 1 ohm, 5 W	.66	.66

Figure H 4.3-2

EXAM H 4.3 CONT'D.

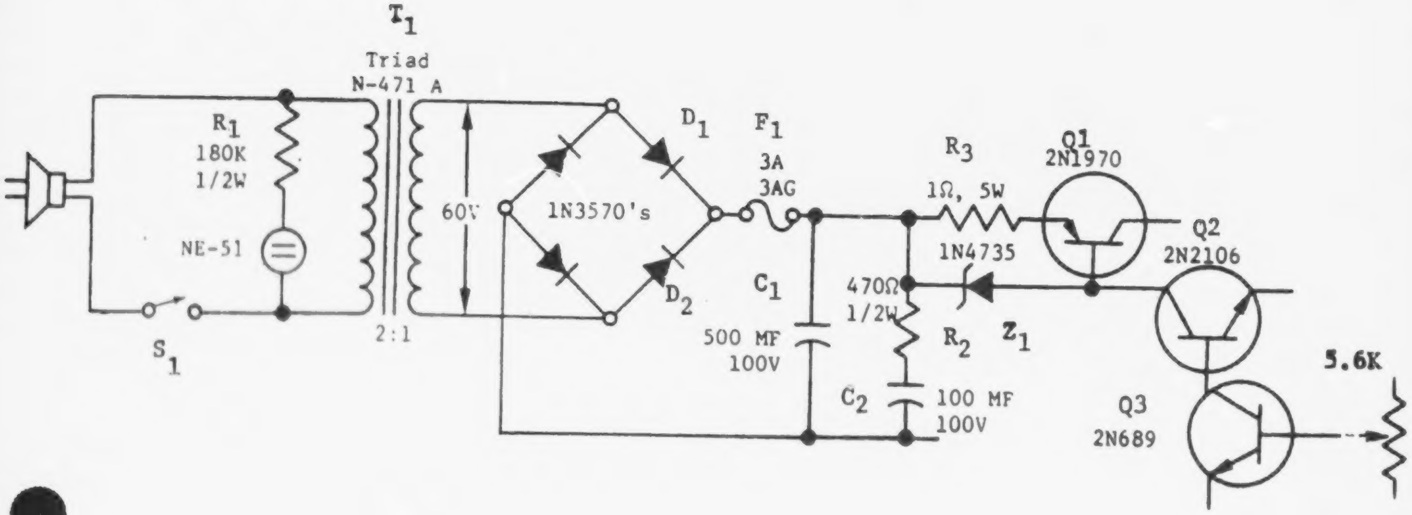

T1
Triad
N-471 A
R1
180K
1/2W
NE-51
S1
2:1
60V
1N3570's
D1
D2
F1
3A
3AG
C1
500 MF
100V
R3
1Ω, 5W
1N4735
470Ω
1/2W
R2
Z1
C2
100 MF
100V
Q1
2N1970
Q2
2N2106
Q3
2N689
5.6K

Figure H 4.3-1

SPECIFY AND REQUISITION SIMPLE ELECTRONIC COMPONENTS

EXAM H 4.1

ANSWER KEY

1. Name of Item
   Specification of Item
   Manufacturer
   Vendor
   Quantity
   Unit Price
   Total Price
   Account, Department, or Person to be Charged
   Date
   Authorization

2. D - IN3570GE Diode, One, $1.62
   T - 954-2571 Trans., One, $22.34
   C - 926-1736 Capac., One 500 MFD-150V, Sprague 1315, $1.80
   C - 926-1784 Capac., One, 100 MFD-150V, Sprague 1420, $1.31
   Z - IN4735 Zener, One, 6.2v, $1.50
   R - 875C7400 Resistor, One, 1 ohm, 5 Watt, Tolerance, IRC, $0.66
   Q - 2N689 Transistor, One, RCA, $9.70

3. $38.93

4. $42.17

ELECTRONICS

RECORDING AND REPORTING TECHNICAL MATERIAL

H 5: COMPOSE TECHNICAL LETTERS

TASK:	Compose technical letters.
PURPOSE:	Although students seldom are asked to write technical letters, technical employees are assigned this task. The purpose of this task is to help you write technical letters.
OBJECTIVE:	Given the necessary information and resources, you will compose at least one technical letter. This letter must contain all the necessary information and be presented in a clear and understandable way.
NOTE:	The objective is limited to form and content. This is not meant to imply that grammar, style and spelling are not important. To go beyond form and content would require developing a long sequence of learning packages which would, in effect, amount to an English course. If you are weak in grammar, spelling or style, you should at least obtain a good manual on composing technical letters and follow its suggestions.

ESTIMATED CLASS TIME: 2 HOURS

COMPOSE TECHNICAL LETTERS

LEARNING STEPS

H 5

READ: Information Sheet H 5.1, "The Components of a Technical Letter."

READ: Information on the components of a technical letter from resources available in your school. See your instructor.

COMPLETE: Activity Sheet H 5.2.

COMPLETE: A technical letter. Compose and write the actual letter using a subject provided by your instructor.

INFORMATION SHEET

H 5.1

THE COMPONENTS OF A TECHNICAL LETTER

The writing of a technical letter is a task most of us do not look forward to doing. Yet these letters provide a vital link in the field of electronics today.

A technical letter should communicate clearly. A letter has six standard parts: (1) The Heading, (2) The Inside Address, (3) The Salutation, (4) The Body, (5) The Complimentary Close, and (6) The Signature. See the sample below:

---

435 Maple Street
Any City, Illinois
August 2, 1985

Mr. John E. Williams
Credit Sales Manager
J. L. Hammond & Sons
1220 Commerce Street
Milwaukee, Wisconsin 53320

Dear Mr. Williams:

This business letter has six standard parts. Personal letters sometimes omit the inside address.

The body is the most important part of the letter. It may have one paragraph or several. Paragraphs are separated by one extra line between them.

Yours very truly,

Warren A. Cooper

INFORMATION SHEET H 5.1 CONT'D.

The Heading: This includes the writer's address and the date.

The Inside Address: This shows the name and address of the person or firm to whom the letter is written.

The Salutation: Use the person's last name, or if you are writing to a company, use "Dear Sir/Madam."

The Body: This is the most important part of a letter. It consists of whatever you want to say.

The Complimentary Close: Just as the salutation greets the reader at the beginning of a letter, the complimentary close says good-by at the end. These two parts of the letter should be consistent as to the degree of formality or informality they express.

Some hints on composing the body are:

A. Clearly state what you are writing about in the first few sentences.
B. Remember the person who will read the letter. Is it a technician? An engineer? The purpose of the letter is to communicate, so you must use the appropriate vocabulary.
C. If background information is necessary, include it, keeping it brief.
D. If you refer to the equipment, give make and model.
E. Do not include schematics in the body of the letter. These should be enclosed separately.
F. Avoid using these expressions:

As a matter of fact
As per your request
As stated above
At your earliest convenience
Await the pleasure of a reply
By return mail
Deem it a privilege
Enclosed herewith please find
Favor of a reply
Hoping to hear from you
I might say
In connection therewith
In due course
Send you herewith
In reference to same
Your kind permission
Kindly inform me

May I take the liberty.
Merit your kind attention
Owing to the fact
Permit me to state
Please advise me
Please be assured
Please find enclosed

Thanking you in advance
This is to advise you
Under separate cover
Wish to advise you
Wish to take this opportunity
In this connection
Your valued assistance
Yours of recent date

INFORMATION SHEET H 5.1 CONT'D.

Remember the purpose of a technical letter is to convey technical information to a specific person. The letter must contain this information in a clear and concise manner and be presented so that the reader comprehends it.

A good letter will be:
- Clear
- Correct
- Complete
- Courteous
- Concise
- Conversational
- Considerate

ACTIVITY SHEET

H 5.2

1. The six parts of a letter are the:

   A.______________________________

   B.______________________________

   C.______________________________

   D.______________________________

   E.______________________________

   F.______________________________

2. The part that contains what you want to say is called the ______________________.

3. The name and address of the person or firm to whom the letter is intended is included in the __________________ .

ACTIVITY SHEET H 5.2

ANSWER SHEET

1. Heading
   Inside Address
   Salutation
   Body
   Complimentary Close
   Signature

2. Body

3. Inside Address

ELECTRONICS

RECORDING AND REPORTING TECHNICAL MATERIAL

H 6: WRITE FORMAL REPORTS OF LABORATORY EXPERIENCES

TASK: Write formal reports of laboratory experiences.

PURPOSE: As a student and, later, as an employee you will write formal reports on laboratory or technical experience. The purpose of this guide is to help you develop the skills necessary for this assignment.

OBJECTIVE: Given the necessary information and resources, you will write at least one report on a laboratory experience. This report will contain all of the necessary information in a clearly understandable way.

NOTE: The objective is limited to form and content. This is not meant to imply that grammar, style and spelling are not important. To go beyond form and content would require developing a long sequence of learning packages which would, in effect, amount to an English course. If you are weak in grammar, style or spelling, you should at least obtain a good manual on writing technical reports and follow its suggestions.

ESTIMATED CLASS TIME: 3 HOURS

WRITE FORMAL REPORTS OF LABORATORY EXPERIENCES

LEARNING STEPS

H 6

READ: Information Sheet H 6.1, "Content of a Formal Laboratory Report."

READ: Information on the content of a formal lab report from resources available in your school. See your instructor.

COMPLETE: This task by writing a formal report of a laboratory experience. This means this task will be assigned to you at a time when your studies require the writing of a formal lab report.

INFORMATION SHEET

H 6.1

THE CONTENT OF A FORMAL LAB REPORT

In general, technicians do not look forward to writing laboratory reports. Yet these reports will be a vital part of your education, and later, as an employee, they will be a vital part of your job.

A good report communicates to those who need the information."

Two ways to improve clarity are to make sure that all information is correct and that it is presented in an understandable way.

The content of a technical report should contain the following:

A. The objective of the experience.
B. The conditions under which you will perform the objective.
C. A list of the materials required to complete the experience.
D. The procedure to be used in the experience:
    a. A step-by-step description of each procedure
    b. Small schematics or diagrams used for each circuit or experience.
    c. The results tabulated in the form of a table. For a more vivid presentation, you may wish to use a type of graph.
    d. A final statement of results.

If a circuit is changed, the above steps should be repeated for each individual procedure.

Remember, laboratory experiences are extremely important. They must be 100% accurate in each area: Set-up, Procedure, and Results.

ELECTRONICS

USING TECHNICAL REFERENCES

I 1: USE OF NUMERICAL INTEGRATED CIRCUITS REFERENCE MANUALS

TASK: Use numerical IC reference manuals to identify manufacturers of various electronic devices.

PURPOSE: This guide will introduce you to technical references, which will aid you in finding the manufacturers of IC chips. After you complete this guide, you should be able to identify an integrated circuit chip's manufacturer and function by its numerical part number.

OBJECTIVE: Given numerical IC reference manuals and a variety of integrated circuits, use numerical IC reference manuals to identify manufacturers of various integrated circuit devices. To master this task, you must score 90% on a performance checklist.

ESTIMATED CLASS TIME: 3 HOURS

USE OF NUMERICAL IC REFERENCE MANUALS

LEARNING STEPS

I 1

READ: Information Sheet I 1.1 on "Numerical IC References."

READ: Information on Numerical IC References from the following resource list.

COMPLETE: Activity Sheet I 1.2 on "Numerical IC References."

COMPLETE: Performance Checklist I 1.3 on "Numerical IC References."

USE OF NUMERICAL IC REFERENCE MANUALS

RESOURCES

1. Manufacturers' Data Books
2. Numerical IC Reference Manuals
3. Cross-Reference Guides
4. Computer Information Services

INFORMATION SHEET

I 1.1

NUMERICAL IC REFERENCES

Many times you are faced with an IC chip, about which you know nothing except the part number. What you need to know is: Who made the device, and what is its function? There are several ways you can find information on this chip, if you must know the part number for the device. Usually there are a couple of numbers printed on the device; one of these numbers is the part number, and the other is probably a "date code". The date code refers to the date the device was manufactured. This aids manufacturers in their quality control. The date code might appear like this: 7814. This could mean 14th week of the year 1978, although this code sequence may vary from manufacturer to manufacturer.

Now that you can distinguish date code from part number, you start tracking down some information about the device. You might try to look for a company logo printed on the chip. Once the device has been traced to the company, then you can check in your data library to see if you have any information on this device. If you do not have the data manual, then you will need to write the company and ask for a data sheet on the device. Figure I 1.1-1 represents a sample of company logos.

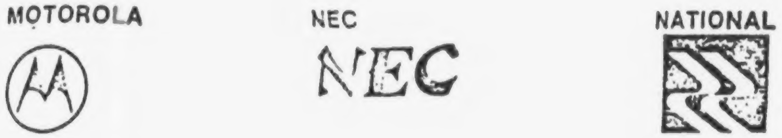


Figure I 1.1-1

A second method, and probably a little more efficient, is to use an IC Numerical Reference Manual. This is a large book listing most of the integrated circuit chips you might come across in an alphanumerical listing. The book is quite easy to use, and with a little practice you will be able to find almost any device you might have. The reference is helpful because it directs you to a page which lists all the manufacturers of the chip and describes its general function (digital latch, interface port driver, etc.). The IC Reference Manual also lists possible cross-references for the chip and addresses for all of the manufacturers who make the device on which you are seeking data. Again, if you need more data than the reference provides, you will need to write the manufacturer and request a data sheet.

INFORMATION SHEET I 1.1 CONT'D.

Large industries often employ one of several computer services to conduct searches for them. The method you use will depend on the sources available to you. The point to remember is that the more you use and know about technical research the easier your job will be.

ACTIVITY SHEET

I 1.2

NUMERICAL IC REFERENCES

On a separate sheet of paper, complete all of the activities called for.

1. Locate 10 or 15 IC chips with valid part numbers.
2. Obtain from your technical library an IC numerical reference manual.
3. Identify each chip's manufacturer.
4. Identify each chip's functions.
5. List the manufacturer's address for each chip.

ACTIVITY SHEET I 1.2

ANSWER SHEET

All answers will depend on chips selected.

PROGRAM: ELECTRONICS

TASK: USE OF NUMERICAL IC REFERENCE MANUALS

TASK # I 1.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE ____________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ____________

TERMINAL PERFORMANCE OBJECTIVE:

Use numerical IC reference manuals to identify manufacturers of various electronic devices.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 40 minutes and must score at least 9 out of 10 points or 90% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 40 minutes and must score 9 out of 10 points or 90%, and all items marked with an asterisk (*) must be satisfactorily completed.

1949

ELECTRONICS

USE OF NUMERICAL IC REFERENCE MANUALS

I 1.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Were clearly marked chips used?	Y N
*2.	Was the proper reference used?	Y N
*3.	Was each manufacturer listed?	Y N
*4.	Was the function of each chip listed?	Y N
*5.	Were all components and reference materials returned to proper location?	Y N

TOTAL POINTS POSSIBLE ____

POINTS NEEDED FOR MASTERY ____

SCORE ____

ELECTRONICS

USING TECHNICAL REFERENCES

I 2: USE OF MANUFACTURER REFERENCE MANUALS

TASK:	Use manufacturers' reference manuals to identify specific characteristics of various electronic devices.
PURPOSE:	This learning guide will introduce you to what are commonly called data sheets and data manuals. These are written by the manufacturer to provide the user with technical information about a group of devices or a single electronic device. After you complete this learning guide you should be able to identify specific characteristics of an electronic device, using data provided by the manufacturer.
OBJECTIVE:	Given the necessary manufacturers' data and various electronic devices, use manufacturers' reference manuals to identify specific characteristics of various electronic devices. To master this task, you must score 90% on a performance checklist.

ESTIMATED CLASS TIME: 3 HOURS

USE OF MANUFACTURER REFERENCE MANUALS

LEARNING STEPS

I 2

READ: Information Sheet I 2.1 on "Data Sheets and Manuals."

COMPLETE: Activity Sheet I 2.2 on "Data Sheets and Manuals."

COMPLETE: Performance Checklist I 2.3 on "Data Sheets and Manuals."

INFORMATION SHEET

I 2.1

DATA SHEETS AND MANUALS

As you are probably aware of at this point in your association with electronics, there are thousands and thousands of electronic devices used in electronics. In the previous learning guide you gained some experience with IC components, and you are now able to identify a numerical part number with a manufacturer. This guide will introduce you to the manufacturer's data for a specific device. This data is usually in the form of a "data manual," which is a book of technical information pertaining to a group of like devices. This data can also be provided in a "data sheet," which is a one or two page information sheet providing technical information on a specific device.

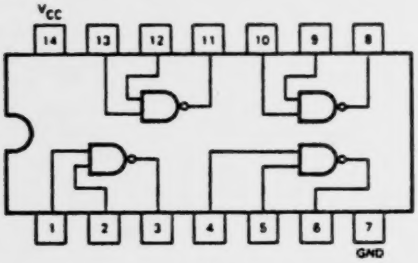
Information pertaining to IC's is usually in the data manual form, leaving the data sheet for special components or larger devices. The data manuals are usually organized by component, family or function, such as TTL data book, CMOS data book, interface components data book, linear devices, data acquisition, etc. Each data manual is further organized by special function; an example for TTL would be as follows: gates, decoders, encoders, counters, shift-registers, etc. Each of these then would be divided into specific component type (AND, OR, NOR, etc.).

The organization of the data manual will vary from one manufacturer to the next, but the overall table of contents will contain the following: a numerical index of all devices in the manual, a selection guide by function, ordering information, circuit characteristics, testing considerations, design considerations, the data itself, definition of symbols, definition of terms used by the manual, package outline information, and reliability data.

The data, which pertains to the component or device, is best explained by an example of a data sheet. Figure I 2.1-1 is a data sheet for a 74 series LS NAND gate. Probably the most important piece of data is the "pinout" of the chip, which shows you which pin connects to what in the chip. Other important information includes "voltage ratings" (minimum and maximum) and "input and output propagation delays." The amount and type of information will, of course, depend upon the component itself; a microprocessor data sheet will have much more information than a data sheet for a quad 2-input NAND chip.

SN54LS00/SN74LS00

QUAD 2-INPUT NAND GATE



GUARANTEED OPERATING RANGES

PART NUMBERS	SUPPLY VOLTAGE			TEMPERATURE
	MIN	TYP.	MAX	
SN54LS00X	4.5 V	5.0 V	5.5 V	−55°C to 125°C
SN74LS00X	4.75 V	5.0 V	5.25 V	0°C to 70°C

X = package type; W for Flatpak, J for Ceramic Dip, N for Plastic Dip. See Packaging Information Section for packages available on this product.

DC CHARACTERISTICS OVER OPERATING TEMPERATURE RANGE (unless otherwise specified)

SYMBOL	PARAMETER		LIMITS			UNITS	TEST CONDITIONS (Note 1)
			MIN	TYP	MAX		
V_{IH}	Input HIGH Voltage		2.0			V	Guaranteed Input HIGH Voltage
V_{IL}	Input LOW Voltage	54			0.7	V	Guaranteed Input LOW Voltage
		74			0.8		
V_{CD}	Input Clamp Diode Voltage			−0.65	−1.5	V	V_{CC} = MIN, I_{IN} = −18 mA
V_{OH}	Output HIGH Voltage	54	2.5	3.4		V	V_{CC} = MIN, I_{OH} = −400 μA, V_{IN} = V_{IL}
		74	2.7	3.4			
V_{OL}	Output LOW Voltage	54,74		0.25	0.4	V	V_{CC} = MIN, I_{OL} = 4.0 mA, V_{IN} = 2.0 V
		74		0.35	0.5	V	V_{CC} = MIN, I_{OL} = 8.0 mA, V_{IN} = 2.0 V
I_{IH}	Input HIGH Current			1.0	20	μA	V_{CC} = MAX, V_{IN} = 2.7 V
					0.1	mA	V_{CC} = MAX, V_{IN} = 10 V
I_{IL}	Input LOW Current				−0.4	mA	V_{CC} = MAX, V_{IN} = 0.4 V
I_{OS}	Output Short Circuit Current (Note 3)		−15		−100	mA	V_{CC} = MAX, V_{OUT} = 0 V
I_{CCH}	Supply Current HIGH			0.8	1.6	mA	V_{CC} = MAX, V_{IN} = 0 V
I_{CCL}	Supply Current LOW			2.4	4.4	mA	V_{CC} = MAX, Inputs Open

AC CHARACTERISTICS: T_A = 25°C (See Chapter 1 for Waveforms)

SYMBOL	PARAMETER	LIMITS			UNITS	TEST CONDITIONS
		MIN	TYP	MAX		
t_{PLH}	Turn Off Delay, Input to Output		5.0	10	ns	V_{CC} = 5.0 V
t_{PHL}	Turn On Delay, Input to Output		5.0	10	ns	C_L = 15 pF

NOTES:

1. For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions for the applicable device type.
2. Typical limits are at V_{CC} = 5.0 V, T_A = 25°C.
3. Not more than one output should be shorted at a time.

Figure I 2.1-1

ACTIVITY SHEET

I 2.2

DATA SHEETS AND MANUALS

1. Contact your instructor for a list of electronic devices.
2. Ask your instructor which component or device specifications you are to research.
3. List the specifications called for.
4. Turn these into your instructor for evaluation.

ACTIVITY SHEET I 2.2

ANSWER SHEET

The answers for this activity will depend on component and specification selection.

PROGRAM: ELECTRONICS

TASK: DATA SHEETS AND MANUALS

TASK # I 2.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE ______________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ______________

PERFORMANCE OBJECTIVE:

Use manufacturers' reference manuals to identify specific characteristics of various electronic devices.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 50 minutes and must score at least 22 out of 25 points or 90% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 50 minutes and must score 22 out of 25 points or 90%, and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

DATA SHEETS AND MANUALS

I 2.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Were the proper references used?	Y N
*2.	Was the proper device found in the reference manual?	Y N
3.	Were the proper specifications listed?	Y N
*4.	Was all information written accurately and neatly?	Y N
*5.	Were all reference materials returned to proper areas?	Y N

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY_____

SCORE _____

1958

ELECTRONICS

USING TECHNICAL REFERENCES

I 3: USE OF REFERENCE MANUALS TO IDENTIFY MANUFACTURERS AND DISTRIBUTORS

TASK:	Use reference manuals to identify manufacturers and distributors of various electronic devices.
PURPOSE:	There are many times when you need to know the manufacturers and distributors for a particular electronic device. This guide will introduce you to the technical references which can be used to research these sources.
OBJECTIVE:	Given all necessary reference manuals and a variety of electronic devices, use reference manuals to identify the distributors of various electronic devices. To master this task you must score 90% on a performance checklist.

ESTIMATED CLASS TIME: 3 HOURS

USE OF REFERENCE MANUALS TO IDENTIFY MANUFACTURERS AND DISTRIBUTORS

LEARNING STEPS

I 3

READ: Information Sheet I 3.1 on "Technical Reference."

COMPLETE: Activity Sheet I 3.2 on "Technical References".

COMPLETE: Performance Checklist I 3.3 on "Use of Reference Manuals to Identify Manufacturers and Distributors."

USE OF REFERENCE MANUALS TO IDENTIFY MANUFACTURERS AND DISTRIBUTORS

RESOURCES

1. Electronic Trade Magazines
2. Local Industry Microfilm Libraries
3. Distributors and Manufacturers' directory, i.e. ELECTRONIC DESIGN'S GOLD BOOK

INFORMATION SHEET

I 3.1

TECHNICAL REFERENCES

In the first learning guide on technical references, you learned how to research manufacturers of integrated circuits. The second guide introduced you to manufacturers' data sheets and manuals. The next guide will give you information on how to find manufacturers and distributors of various electronic devices other than integrated circuits.

As you are aware, there are many electronic devices used in the electronics industry other than IC's and transistors. Examples of these devices, to list only a few, would include solid state relays, wire, indicator lights, sockets for IC's and transistors, motors, wire ties, etc. This list could go on and on!!

There will be many times when you will need technical information, in one form or another, about a particular device. You might need to know who makes the device, so you can order another; or you may need technical information in the form of a data sheet on the device. You can read through any trade magazine which might be available. These can often be excellent sources of information, and often they are free for the asking. If your local industry subscribes to a microfilm service providing technical information, you can request access. Perhaps the best resource is to purchase or borrow a reference called the "GOLD BOOK," which is a listing of manufacturers and distributors.

The directory section of the "Gold Book" (or simply, "the directory") is divided into the following sections: "Product directory," which gives a listing by products, e.g., amplifiers, crystals, power supplies, etc. The next section is the "trade name directory." This allows you to locate the device by its trade name if you can't find it in the product directory section. The third section is the "manufacturers' directory," which allows you to obtain address and telephone information for the manufacturer. The last section refers to the "distributors" of electronic devices, either by alphabetic or geographic listing. Knowing the distributor is often necessary, because some manufacturers will only sell through a distributor.

INFORMATION SHEET I 3.1 CONT'D.

As with any technical research, the best way to gain experience is to actually do it. It is suggested that you spend some time looking over some of the sources that have been listed in this guide and practice finding the distributor and manufacturer for some electronic device on which you might want more information.

ACTIVITY SHEET

I 3.2

TECHNICAL REFERENCES

1. Obtain from your instructor several electronic devices.
2. List the manufacturer of each and give the address and phone number for each.
3. List the distributor of each and provide address and phone information also.

ACTIVITY SHEET I 3.2

ANSWER SHEET

The answers for this activity will depend on the electronic device selection.

PROGRAM: ELECTRONICS

TASK: USE OF REFERENCE MANUALS TO IDENTIFY MANUFACTURERS AND DISTRIBUTORS

TASK # I 3.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ________________ EVALUATION SITE ____________

EVALUATOR'S NAME ______________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT ____________

PERFORMANCE OBJECTIVE:

Use reference manuals to identify manufacturers and distributors of various electronic devices.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 50 minutes and must score at least 22 out of 25 points or 90% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must complete the performance within 50 minutes and must score 22 out of 25 points or 90%, and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

USE OF REFERENCE MANUALS TO IDENTIFY MANUFACTURERS AND DISTRIBUTORS

I 3.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO	
1.	Were the proper references used?	Y	N
2.	Did student find the proper distributor?	Y	N
3.	Did student find the proper manufacturer?	Y	N
*4.	Was all information written accurately and neatly?	Y	N
*5.	Were all reference materials returned to proper areas?	Y	N

TOTAL POINTS POSSIBLE ______

POINTS NEEDED FOR MASTERY ______

SCORE ______

ELECTRONICS

USING TECHNICAL REFERENCES

I 4: USE OF REFERENCE MANUALS TO CROSS-REFERENCE MANUFACTURERS

TASK:	Use reference manuals to cross-reference various electronic devices between manufacturers.
PURPOSE:	There will be numerous times when you will need to replace a component or device with a duplicate component. To perform this task you will need to know how to use cross-reference manuals. After completing this learning guide, you should be able to cross-reference a device from one manufacturer to another.
OBJECTIVE:	Given access to all necessary reference manuals and various electronic devices, use reference manuals to cross-reference various electronic devices between manufacturers. To master this task you must score 90% on a performance checklist.

ESTIMATED CLASS TIME: 3 HOURS

USE OF REFERENCE MANUALS TO CROSS-REFERENCE MANUFACTURERS

LEARNING STEPS

I 4

READ:	Information Sheet I 4.1 on "Cross-Reference Manuals."
COMPLETE:	Activity Sheet I 4.2 on "Cross-Reference Manuals."
COMPLETE:	Performance Checklist I 4.3 on "Cross-Reference Manuals."

USE OF REFERENCE MANUALS TO CROSS-REFERENCE MANUFACTURERS

RESOURCES

1. RCA, SK Series Solid State Replacement Guide
2. ECG Semiconductors Master Replacement Guide

INFORMATION SHEET

I 4.1

CROSS-REFERENCE MANUALS

As a person working in the field of electronics, you will be required to replace components which have malfunctioned with similar or duplicate components. To perform this task you will need to be familiar with cross-reference manuals. A "cross-reference manual" is a book which allows you to look up your part number and replace it with a component having the same electrical parameters.

Using one of these guides is usually quite easy. First, identify the correct part number on your device. Numerical part numbers are listed first, followed by those with alphanumeric identifiers. For example, 023478 would be listed before MPS 20. Parts with a dash after a series of numbers are listed ahead of parts with a letter after the same series of numbers. For example, 48-1234 would be listed before 48A-1234. Parts starting with a letter are listed in alphabetical order of the letters occurring before a dash or number. Example: MPS-A20 would be listed before MPSA20.

Now that you understand the listing of numbers, you can find the replacement part number. The next step is to verify that the new part does have the same parameters as the old part. This can be checked in the front portion of the cross-reference guide by looking in the section giving data on the new device. You should check the key parameters to make sure that the new component meets or exceeds the parameters of the original.

In the event that the cross-reference section does not show a replacement, you should first consider the possibility of a "no suffix" or "different suffix" replacement. (i.e., 2SC281 E is not found in the cross-reference section. However, 2SC281 is found, so the next step would be to check the parameters for the recommended replacement. If they are the same, then make the substitution. The best method of learning to make successful cross-references is to practice. Ask your instructor to provide you with some part numbers for substitution, and then practice with a manual, making the cross-reference.

ACTIVITY SHEET

I 4.2

CROSS-REFERENCE MANUALS

On a separate sheet of paper complete the following activities:

1. Obtain from your instructor several electronic devices.
2. List the cross-reference for each of these devices.

ACTIVITY SHEET I 4.2

ANSWER SHEET

The cross-references will depend on the devices used.

PROGRAM: ELECTRONICS

TASK: USE OF REFERENCE MANUALS TO CROSS-REFERENCE MANUFACTURERS

TASK # I 4.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ____________________ EVALUATION SITE __________

EVALUATOR'S NAME __________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT __________

TERMINAL PERFORMANCE OBJECTIVE:

Use reference manuals to cross-reference various electronic devices between manufacturers.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete at least 22 out of 25 points or 90% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE EVALUATOR:

The student will contact you when ready for evaluation. The student must score 22 out of 25 points or 90%, and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

USE OF REFERENCE MANUALS TO CROSS-REFERENCE MANUFACTURERS

I 4.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Were the proper references used?	Y N
*2.	Did student find the proper device in the reference manual?	Y N
3.	Were the proper specifications listed?	Y N
*4.	Was all information written accurately and neatly?	Y N
*5.	Were all reference materials returned to proper areas?	Y N

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

SCORE _____

ELECTRONICS

USING TECHNICAL REFERENCES

I 5: USE OF MANUALS TO DETERMINE MAINTENANCE PROCEDURES

TASK: Use manuals to determine maintenance procedures.

PURPOSE: Part of the job of an electronics technician is to provide periodic maintenance to equipment. A technician must know how to use equipment manuals to determine maintenance procedures. After you complete this learning guide, you should be familiar with maintenance procedures and be able to use be them to provide routine maintenance.

OBJECTIVE: Given access to equipment manuals, use manuals to determine maintenance procedures. To master this task you must score 90% on a performance checklist.

ESTIMATED CLASS TIME: 3 HOURS

USE OF MANUALS TO DETERMINE MAINTENANCE PROCEDURES

LEARNING STEPS

I 5

READ: Information Sheet I 5.1 on "Maintenance Procedures."

COMPLETE: Activity Sheet I 5.2 on "Maintenance Procedures."

COMPLETE: Performance Checklist I 5.3 on "Maintenance Procedures."

INFORMATION SHEET

I 5.1

MAINTENANCE PROCEDURES

As an electronics technician, not all of your time will be spent fixing broken equipment; some of it will be used performing periodic maintenance following a standard maintenance procedure.

Most equipment comes with some form of maintenance manual as well as an operation manual. Some of the major sections you might find in a maintenance manual, depending on the complexity of the procedure, include a general description of the equipment, an "operations" section, installation and checkout procedures, a section on the theory of operation, and, finally, a section on maintenance which includes a maintenance procedure, a list of maintenance tools and aids, and a parts list.

The maintenance procedure will vary from one piece of equipment to another, and the detail provided will depend on the equipment's complexity. Included in this guide is a topical listing of the maintenance section from a maintenance manual for a flexible disk drive. Study this listing to acquaint yourself with what might be considered a typical maintenance procedure. Your best introduction will be to read several manuals your instructor can provide and perform the procedures on equipment set aside for this purpose.

INFORMATION SHEET I 5.1 CONT'D.

MAINTENANCE

6.1 INTRODUCTION 6-1
6.2 MAINTENANCE TOOLS 6-1
6.3 TROUBLESHOOTING 6-1
    6.3.1 DC Voltage and Signal Check 6-1
6.4 ADJUSTMENT PROCEDURES 6-4
    6.4.1 Write Splice Check and Adjustment 6-4
    6.4.2 Actuator Alignment 6-8
    6.4.3 Clamshell Closed Switch Adjustment 6-11
    6.4.4 Track 00 Optimal Sensor Adjustment 6-12
    6.4.5 Diskette Ejector 6-12
    6.4.6 Diskette Load Plate Adjustment 6-13
    6.4.7 Head Unload Clearance 6-14
    6.4.8 Band Alignment 6-14
    6.4.9 Azimuth Adjustment 6-15
    6.4.10 Track Zero Stop Adjustment 6-15
6.5 REMOVAL AND REPLACEMENT PROCEDURES 6-15
    6.5.1 Printed Wire Assembly (PWA) 6-17
    6.5.2 Head Replacement 6-17
    6.5.3 Drive Motor Assembly 6-20
    6.5.4 Actuator Replacement 6-20
6.6 FREQUENCY CONVERSION 6-20
    6.6.1 Operating Frequency Conversion Procedure . . 6-20

MAINTENANCE AIDS

7.1 INTRODUCTION 7-1
7.2 PHYSICAL DESCRIPTION (Logic) 7-1
7.3 USE OF RELATIVE LEVEL INDICATORS 7-1
7.4 INTEGRATED CIRCUITS 7-2

PARTS DATA (75888344)

8.1 INTRODUCTION 8-1
8.2 ILLUSTRATIONS 8-1
8.3 PARTS LIST 8-1
8.4 PRODUCT CONFIGURATIONS 8-1
    8.4.1 Hardware Product Configurator (HPC) 8-1

ACTIVITY SHEET

I 5.2

MAINTENANCE PROCEDURES

On a separate sheet of paper, complete the following activities:

1. Obtain from your instructor a piece of equipment and maintenance manual.
2. Following maintenance procedures in the maintenance manual, perform the necessary periodic maintenance.

ACTIVITY SHEET I 5.2

ANSWER SHEET

Answers will depend on equipment and manual selected. A piece of equipment which might be used is an old scope.

PROGRAM: ELECTRONICS

TASK: USE OF MANUALS TO DETERMINE MAINTENANCE PROCEDURES

TASK # I 5.3

PERFORMANCE/PRODUCT CHECKLIST

STUDENT'S NAME ______________________ EVALUATION SITE __________

EVALUATOR'S NAME ____________________ PERFORMANCE ATTEMPT 1 2 3 4

DATE OF ATTEMPT __________

TERMINAL PERFORMANCE OBJECTIVE:

Use of Manuals to Determine Maintenance Procedures.

DIRECTIONS TO THE STUDENT:

Before attempting this task for mastery, carefully review this checklist. You will be evaluated on the basis of this checklist. When you feel you are ready for evaluation, contact your instructor. You must complete your performance within 55 minutes and must score at least 22 out of 25 points or 90% for mastery. Critical items are marked with an asterisk (*). These items must be satisfactorily completed.

DIRECTIONS TO THE STUDENT:

The student will contact you when ready for evaluation. The student must complete the performance within 55 minutes and must score 22 out of 25 points or 90%, and all items marked with an asterisk (*) must be satisfactorily completed.

ELECTRONICS

USE OF MANUALS TO DETERMINE MAINTENANCE PROCEDURES

I 5.3

CRITICAL ITEMS	ITEMS TO BE OBSERVED	RATING YES/NO
1.	Was the maintenance procedure followed and were all steps performed?	Y N
*2.	Were the proper tools and equipment used?	Y N
*3.	Were all adjustments made accurately?	Y N
*4.	Were equipment and tools used safely?	Y N
5.	Were all materials and equipment returned to proper areas?	Y N

TOTAL POINTS POSSIBLE _____

POINTS NEEDED FOR MASTERY _____

SCORE _____

1983

ELECTRONICS

CONTROL SYSTEMS AND DEVICES

J 1: INTRODUCTION TO CONTROL SYSTEMS

TASK: Distinguish between a manually-operated and automatically-operated control system.

PURPOSE: To familiarize the student with the difference between manually and automatically operated control systems.

OBJECTIVE: Given a list of controls, you must be able to distinguish between manually and automatically operated control systems. To master this task, you must score 90% on a performance check list.

ESTIMATED CLASS TIME: 2 HOURS

INTRODUCTION TO CONTROL SYSTEMS

LEARNING STEPS

J 1

READ: Information Sheet J 1.1 on "Manually and Automatically Operated Control Systems."

READ: Information on manually and automatically operated control systems from the following resource list.

COMPLETE: Activity Sheet J 1.2 on manually and automatically operated control systems.

COMPLETE: Written Examination J 4.3 covering manually and automatically operated control systems, upon completion of Task J 4.3.

1985

INTRODUCTION TO CONTROL SYSTEMS

RESOURCES

1. Timothy J. Maloney, INDUSTRIAL SOLID-STATE ELECTRONICS DEVICES AND SYSTEMS, (Prentice-Hall, Inc., 1986). Second Edition.
2. J. A. Sam Wilson, CONTROL ELECTRONICS WITH AN INTRODUCTION TO ROBOTICS, (SRA, Inc., 1986).

1986

INFORMATION SHEET

J 1.1

MANUALLY AND AUTOMATICALLY OPERATED CONTROL SYSTEMS

In Electronics there is a widespread use of control circuitry to control the operation of machines, motors and solid-state equipment. The early control devices were switches and relays, referred to as "dynamic controls," which are devices with moving parts. The more modern up-to-date control devices are referred to as "static devices," with no moving parts--or simply, electronic controls. There are many control systems which are hybrid systems incorporating both static and dynamic controls. Static and dynamic controls are used partly or wholly in manually or automatically operated control systems.

Systems which require the intervention of an operator are called manual systems. If the system controls are located at a remote station and require the intervention of an operator, the system is semiautomatic. Fully automatic systems require an operator only to stop and start the systems.

Manually operated and automatically operated control systems can also be classified as open—loop and closed—loop control systems (Task J 2).

1987

ACTIVITY SHEET

J 1.2

On a separate sheet of paper, complete all of the activities called for:

1. Obtain from your instructor several diagrams of control systems.
2. Identify each diagram as either a manually or automatically operated control system.

1988

ACTIVITY SHEET J 1.2

ANSWER SHEET

The answers to this activity will depend on the diagrams selected.

1989

ELECTRONICS

CONTROL SYSTEMS AND DEVICES

J 2: OPEN AND CLOSED-LOOP CONTROL

TASK:	Distinguish between an open and closed-loop control system.
PURPOSE:	As an electronics technician, you will be expected to repair and troubleshoot equipment comprised of open-loop and closed-loop control systems. To correctly repair or troubleshoot control systems, the technician must be able to distinguish between open and closed-loop control systems.
OBJECTIVE:	Given diagrams of control systems, the student must be able to distinguish between open and closed-loop control systems.

ESTIMATED CLASS TIME: 4 HOURS

OPEN AND CLOSED-LOOP CONTROL

LEARNING STEPS

J 2

READ: Information Sheet J 2.1 on "Open and Closed-Loop Control Systems."

READ: Information on open and closed-loop control systems from the following resource list.

COMPLETE: Activity Sheet J 2.2 on "Open and Closed-Loop Control Systems."

COMPLETE: Written Examination J 4.3 on open and closed-loop control systems upon completion of Task J 4.

OPEN AND CLOSED-LOOP CONTROL

RESOURCES

1. Timothy J. Maloney, INDUSTRIAL SOLID-STATE ELECTRONICS DEVICES AND SYSTEMS, (Prentice-Hall, Inc., 1986). Second Edition.

2. J. A. Sam Wilson, CONTROL ELECTRONICS WITH AN INTRODUCTION TO ROBOTICS, (SRA, Inc., 1986).

INFORMATION SHEET

J 2.1

OPEN AND CLOSED-LOOP CONTROL SYSTEMS

There are many different types of open-loop and closed-loop control systems. Control systems are defined by their actuating device. An "actuator" is a device that does useful work. An open-loop control system is also considered a non-self-correcting system; a closed-loop control system is considered a self-correcting control system.

An open-loop control system requires human intervention to ensure proper system operation. An example of an open loop system is the automobile. If an automobile turns a corner, without human intervention the automobile would continue to turn in a circle. In the automobile open-loop control system, the human acts as the correcting device, preventing the automobile from running over the curb.

A closed-loop control system (CLCS) does not require human intervention to maintain proper operation. The CLCS uses a feedback system for the self-correcting action. A CLCS which controls an object's physical position is called a servo system.

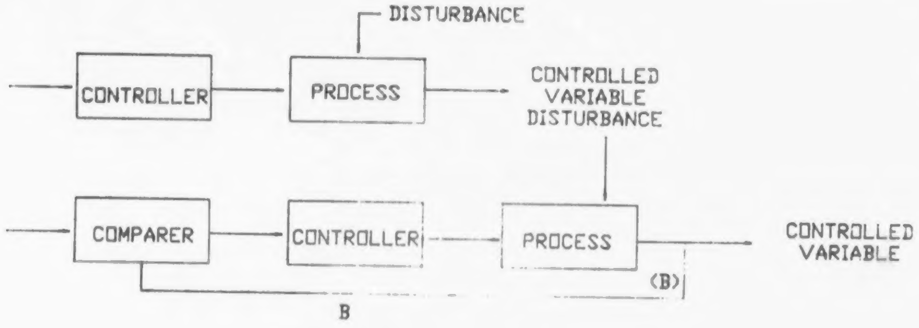


Figure J 2.1-1

In Figure J 2.1-1 the block diagram does not show any lines coming back to the controller device to close the loop. This is an example of an open-loop control system. All open-loop control systems lack the ability to compare the actual position of the controlled variable to the desired position.

The block diagram, Figure B, includes a comparator which compares the setting and the actual position of the controlled variable. The output of the comparator is the difference between the two values. Because the controlled variable feeds back to the comparator, this is a closed-loop control system.

ACTIVITY SHEET

J 2.2

OPEN AND CLOSED-LOOP CONTROL SYSTEMS

On a separate sheet of paper, complete all of the activities called for:

1. Obtain from your instructor various block and schematic diagrams.
2. Identify each diagram and schematic as an open-loop or closed-loop control system.

1994

ACTIVITY SHEET J 2.2

ANSWER SHEET

The answers to this activity will depend on the block and schematic diagrams selected.

ELECTRONICS

CONTROL SYSTEMS AND DEVICES

J 3: CLOSED-LOOP CONTROL SYSTEM ANALYSIS

TASK: Explain the purpose of each of the blocks in a closed-loop control system (CLCS) block diagram.

PURPOSE: It is necessary for the technician to understand the purpose of each of the blocks in a closed-loop control system. This knowledge will assist the technician in maintaining the control systems. This learning guide will explain the purposes and identify each of the blocks in a closed-loop control system block diagram.

OBJECTIVE: Given a written examination, the student will identify the blocks of a closed-loop control system and state the purpose of each block. To master this task, the student must score 90% on the written examination.

ESTIMATED CLASS TIME: 5 HOURS

CLOSED-LOOP CONTROL SYSTEM ANALYSIS

LEARNING STEPS

J 3

READ: Information Sheet J 3.1 on "The Purpose of Each of the Blocks in a Closed-Loop Control System (CLCS) Block Diagram."

READ: Information on the purpose of each of the blocks in a closed-loop control system (CLCS) block diagram from the following resource list.

COMPLETE: Activity Sheet J 3.2 on "The Purpose of Each of the Blocks in a Closed-Loop Control System (CLCS) Block Diagram."

COMPLETE: Written Examination J 4.3 on the purpose of each of the blocks in a closed-loop control system (CLCS) block diagram upon completion of J 4.

1997

CLOSED-LOOP CONTROL SYSTEM ANALYSIS

RESOURCES

1. Timothy J. Maloney, INDUSTRIAL SOLID-STATE ELECTRONICS DEVICES AND SYSTEMS, (Prentice-Hall, Inc., 1986). Second Edition.
2. J. A. Sam Wilson, CONTROL ELECTRONICS WITH AN INTRODUCTION TO ROBOTICS, (SRA, Inc., 1986).
3. James T. Humphries and Leslie P. Sheets, INDUSTRIAL ELECTRONICS, (Breton Publishers, 1983).

INFORMATION SHEET

J 3.1

THE PURPOSE OF EACH OF THE BLOCKS IN A CLOSED-LOOP CONTROL SYSTEM BLOCK DIAGRAM

A closed-loop control system (CLCS) is a group of components organized to perform an end function with a large power gain from input to output. A block diagram shows the functional elements of a CLCS and the signal flow between the blocks, but it does not show the connection between the actual components. CLCS's are classified according to the "error reducer" or "prime mover." A CLCS is more commonly referred to as a "servo system" because it employs feedback and does not require human intervention to complete a task. To be considered a servo system, the group of organized components must be able to accept an order, evaluate the present conditions, compare the desired outcome with the present conditions, generate a correcting order, and obey or act on the correcting order. A typical CLCS block diagram is shown in Figure J 3.1-1

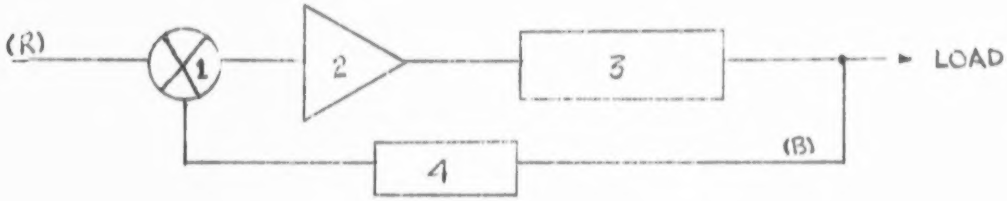


Figure J 3.1-1

The line marked input (R) is the "command" or order from an electrical or mechanical control station. The input may be a reference signal or a positioning command to move a load.

Block 1, The Comparator is also referred to as an "error detector" or "summation point." The purpose of the error detector is to compare the input (R) with the response (B) and generate an error signal if there is a difference between the two signals. The comparator may be a "summing network." In that case, it will compare two electrical signals and generate an electrical difference signal. If the electrical signals being compared are Alternating Current (AC) signals, they must be 180 degrees out of phase with each other. If the signals being compared are both Direct Current (DC) signals, then they must be of opposite polarity.

Some comparators are electromechanical and require the use of a "feedback transducer." The purpose of the feedback transducer (Block 4) is to ensure that the feedback signal is compatible with the input signal. If the input is an electrical signal positioning a mechanical load, then the feedback must be mechanical. The comparator must be capable of comparing these two signals; therefore the feedback must be changed from a mechanical signal into an electrical signal. The opposite may also be necessary, converting from an electrical to a mechanical signal to be compatible. In either case, the device must be one that has an electrical and a mechanical input with an electrical or mechanical output.

Block 2, the "amplifier," is a group of electrical/electronic or mechanical components connected to increase the amplitude or magnitude of the error signal. The amplifier output is referred to as an amplified error signal which is the input to the prime mover or error reducer.

Block 3, the "prime mover" or error reducer, identifies the type of servo control system. The term "prime mover" identifies the system component that does the actual work. Typical prime movers include mechanical, electrical, electronic, hydraulic, pneumatic or a combination of these classes. For example, the combination of an electrical motor and hydraulic system is called an "electrohydaulic servo system." This combination may be confusing because it contains two different classifications for the prime mover. A technically more correct way of identifying this servo system is to say, "a hydraulic servo controlled by an electrical motor." All types and classifications operate on the same basic servo theory; they act on an input (error signal) to position a load or correct an operating level. The error reducer's output actually positions the load device and functions as the input to the feedback transducer.

ACTIVITY SHEET

J 3.2

THE PURPOSE OF EACH OF THE BLOCKS IN A CLOSED-LOOP CONTROL SYSTEM BLOCK DIAGRAM

1. Describe a closed-loop control system block diagram.
2. Explain the function of each of the blocks in a closed-loop control system block diagram.

ACTIVITY SHEET J 3.2

ANSWER SHEET

1. A closed-loop control system (CLCS) is a group of components organized to perform an end function.

2. A CLCS block diagram consists of the following components: an input device, a comparator, an error reducer and a feedback transducer, if required. The most important requirement is the feedback; without it, this system could not be classified as a servo system.

   The input is a command from another station which is not an integral part of the servo system.

   The comparator, or error detector, is an electrical and mechanical device used to compare the input with the feedback; if there is a difference, it will generate an error signal. The comparator output feeds the amplifier.

   The amplifier takes the low level input signal and, through a group of electrical/electronic or mechanical components, increases the amplitude or magnitude of the input, calling it the amplified error signal, and feeds it to the error reducer or prime mover.

   The prime mover, or error reducer, is the component which identifies the type or classification of the servo system. It may be an electrical motor, electronic device, mechanical gearing, hydraulic motor, pneumatic motor or a combination of these classifications. The prime mover output controls the position of the load and functions as the input to the feedback transducer.

   The feedback transducer functions in a servo system to ensure that the feedback signal is compatible with the input. Essentially, if the input is electrical, the feedback must also be electrical. If the load is mechanical, the feedback must be converted from a mechanical signal to an electrical signal to be fed to the comparator.

ELECTRONICS

CONTROL SYSTEMS AND DEVICES

J 4: CLOSED-LOOP CONTROL SYSTEM OPERATION

TASK: State the characteristics of a good closed-loop control system (CLCS).

PURPOSE: A technician must recognize the components of a servo system and determine whether or not they are functioning correctly. To develop techniques necessary to maintain servo systems, the technician must understand the characteristics of a good closed-loop control system (CLCS).

OBJECTIVE: Select the statement that best describes the characteristics of a good closed-loop control system (CLCS).

ESTIMATED CLASS TIME: 5 HOURS

CLOSED-LOOP CONTROL SYSTEM OPERATION

LEARNING STEPS

J 4

READ: Information Sheet J 4.1 on "The Characteristics of a Good Closed-Loop Control System (CLCS)."

READ: Information on the characteristics of a good closed-loop control system (CLCS) from the following resource list.

COMPLETE: Activity Sheet J 4.2 on the "Characteristics of a Good Closed-Loop Control System (CLCS)."

COMPLETE: Written Examination J 4.3 on the characteristics of a good closed-loop control system (CLCS). This examination also includes items covering the first three tasks.

CLOSED-LOOP CONTROL SYSTEM OPERATION

RESOURCES

1. Timothy J. Maloney, INDUSTRIAL SOLID-STATE ELECTRONICS DEVICES AND SYSTEMS, (Prentice-Hall, Inc., 1986). Second Edition.

2. J. A. Sam Wilson, CONTROL ELECTRONICS WITH AN INTRODUCTION TO ROBOTICS, (SRA, Inc., 1986).

3. James T. Humphries and Leslie P. Sheets, INDUSTRIAL ELECTRONICS, (Breton Publishers, 1983).

INFORMATION SHEET

J 4.1

CHARACTERISTICS OF A GOOD CLOSED-LOOP CONTROL SYSTEM

There are many applications of closed-loop control systems (CLCS) in Electronics. Characteristically, CLCS's are rated in terms of "fidelity." Fidelity can be translated into terms of accuracy and stability. In this information sheet, a good CLCS will be defined by discussing the accuracy and stability of a "servomechanism."

Accuracy is a measure of how close the servomechanism is to the final position without deviation. To be accurate, the CLCS must be able to reduce the error signal from the comparator to a minimum or "null" voltage. The accuracy is affected by how rapidly the load responds to the order. The speed of response must be rapid but controllable; if it is not controlled, the rapid response time means the load device may not stop at the desired point, but may oscillate around the desired point. Oscillations are adjusted to a minimum by a dampening control. However, the dampening must be adjusted correctly or the load response may either be sluggish or too rapid. "Over-damped" means the response is slow; it may not reach the null point. When not enough control signal has been applied, the system is said to be "under-damped", and it will have sustained oscillations about the "point of correspondence" or desired point. Correctly adjusted, the system is said to be "critically damped", and the load will arrive at the point of correspondence rapidly without oscillations or overshoots.

Stability is a measure of how closely the output follows the input without oscillating about the ordered position. If the CLCS hunts for the desired controlled output, this means the CLCS "overshoots" the desired position, thereby generating another error signal in the opposite position until the system settles down and aligns with the ordered position. Such overshoots or hunting could be severe enough for the system to shake itself apart. To eliminate this problem, servo systems employ a variable resistance (negative) feedback signal in the amplifier stage which will adjust out the hunting effects.

INFORMATION SHEET J 4.1 CONT'D.

To be considered a good closed-loop control system, a servomechanism must respond to an order rapidly, accurately and stably, without oscillating or overshooting the desired point.

ACTIVITY SHEET

J 4.2

CHARACTERISTICS OF A GOOD CLOSED-LOOP CONTROL SYSTEM

1. Define a good closed-loop control system.
2. Define the term "accuracy."
3. Explain how accuracy relates to a good closed-loop control system.
4. Define the term "stability."
5. Explain how stability relates to a good closed-loop control system.

ACTIVITY SHEET J 4.2

ANSWER SHEET

1. In a good closed-loop control system, a servomechanism must respond to an order rapidly, accurately and stably without oscillating or overshooting the desired point.

2. Accuracy is a measure of how close the servomechanism is to the final point without deviation.

3. Accuracy means the CLCS must be able to reduce the comparator output (error signal) to a minimum or zero voltage. To do this, the servo system must be critically damped to avoid oscillations and overshoots about the point of correspondence.

4. Stability is a measure of how closely the output follows the input without oscillating about the ordered position or point of correspondence.

5. Unstable operation is an undesirable characteristic in a good CLCS. Unstable operation means the system overshoots or hunts for the desired point. This unstable operation is reduced or eliminated in the amplifier stage by adjusting the negative feedback variable resistor called the stability adjust.

CLOSED-LOOP CONTROL SYSTEM OPERATION

EXAM

J 4.3

DIRECTIONS:

The purpose of this examination is to determine whether or not you have understood the information on manually and automatically operated control systems, open and closed-loop control systems, the purpose of each of the blocks in a closed-loop system block diagram and the characteristics of a good closed-loop control system. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Shade in the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on the answer sheet; use a #2 pencil to mark your answers. DO NOT WRITE ON THIS TEST!!!! To master this examination, you must score 90% on each of the tasks being tested.

EXAM J 4.3 CONT'D.

1. Manual controls require the operator to perform each function with on-off switches.

   A. True
   B. False

2. Fully automatic controls operate without the need for someone to perform the switching functions.

   A. True
   B. False

3. A toggle switch is a/an ________________ control device.

   A. automatic
   B. manual

4. A relay is a/an ________________ control device.

   A. automatic
   B. manual

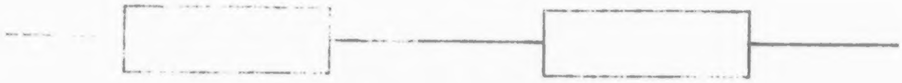


Figure J 4.3-1

5. Figure J 4.3-1 is the diagram of a/an ________________ loop control system.

   A. open
   B. closed

6. Figure J 4.3-2 is a diagram of a/an ______________loop control system.

   A. open
   B. closed

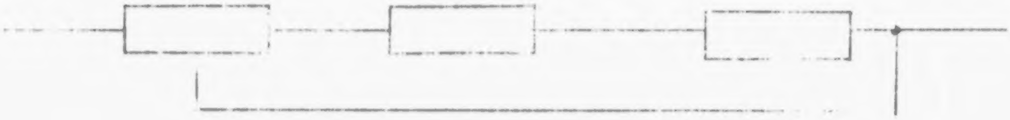


Figure J 4.3-2

EXAM J 4.3 CONT'D.

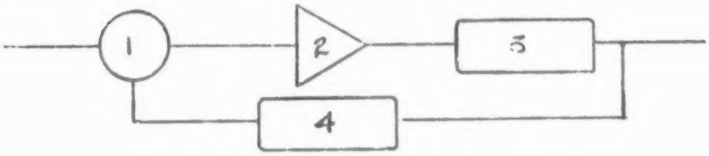


Figure J 4.3-3

Using the following answers, identify each of the blocks in Figure J 4.3-3 for Questions 7 through 10:

A. error reducer
B. error detector
C. load device
D. amplifier
E. feedback transducer
F. command

7. Block #1 is the ____________________.

8. Block #2 is the ____________________.

9. Block #3 is the ____________________.

10. Block #4 is the ____________________.

11. What is the purpose of Block #1 in Figure J 4.3-3?

A. convert the feedback to a signal compatible with the input
B. compare the input with the feedback
C. reduce the error signal
D. amplify the error signal

12. What is the purpose of Block #2 in Figure J 4.3-3?

A. convert the feedback to a signal compatible with the input
B. compare the input with the feedback
C. reduce the error signal
D. amplify the error signal

13. What is the purpose of Block #3 in Figure J 4.3-3?

A. convert the feedback to a signal compatible with the input
B. compare the input with the feedback
C. reduce the error signal
D. amplify the error signal

EXAM J 4.3 CONT'D.

14. What is the purpose of Block #4 in Figure J 4.3-3.

    A. convert the feedback to a signal compatible with the input
    B. compare the input with the feedback
    C. reduce the error signal
    D. amplify the error signal

15. A good closed-loop control system (CLCS) is one which _______________ about the point of correspondence.

    A. overshoots and oscillates
    B. is critically damped and does not overshoot or oscillate
    C. moves rapidly and oscillates
    D. is stable and hunts

16. Accuracy is measured by how close the servomechanism is to the final point without deviation.

    A. True
    B. False

17. Stability measures how closely the output follows the input without oscillating around the ordered position.

    A. True
    B. False

EXAM J 4.3

ANSWER KEY

1. A
2. A
3. B
4. A
5. A
6. B
7. B
8. D
9. A
10. E
11. B
12. D
13. C
14. A
15. B
16. A
17. A

ELECTRONICS

CONTROL SYSTEMS AND DEVICES

J 5: ANALYSIS OF CONTROL MODES

TASK: List and explain the operation and describe the characteristics of the five control modes for closed-loop control systems.

PURPOSE: To improve the operation of a closed-loop control system, a controller is added to the block diagram, enabling the system to regulate the controlled variable. This learning guide will enable you to identify the different control modes, explaining their characteristics and operation.

OBJECTIVE: Upon completion of this task, the student will be able to list the closed-loop control system control modes, explain their operation and describe their characteristics. To master these tasks, the student must score 90% on the Activity Sheet.

ESTIMATED CLASS TIME: 12 HOURS

ANALYSIS OF CONTROL MODES

LEARNING STEPS

J 5

READ:	Information Sheet J 5.1 on "The Closed-Loop Control System Control Modes Including Their Operation and Characteristics."
READ:	Information on the closed-loop control system control modes, including their operation and characteristics from the following resource list.
COMPLETE:	Activity Sheet J 5.2 on "The Closed-Loop Control System Control Modes," including their operation and characteristics.

ANALYSIS OF CONTROL MODES

RESOURCES

1. Timothy J. Maloney, INDUSTRIAL SOLID-STATE ELECTRONICS DEVICES AND SYSTEMS, (Prentice-Hall, Inc., 1986). Second Edition.
2. J. A. Sam Wilson, CONTROL ELECTRONICS WITH AN INTRODUCTION TO ROBOTICS, (SRA, Inc., 1986).
3. James T. Humphries and Leslie P. Sheets, INDUSTRIAL ELECTRONICS, (Breton Publishers, 1983).
4. Robert L. Hoekstra, ROBOTICS AND AUTOMATED SYSTEMS, (South-Western Publishing Co., 1986).

INFORMATION SHEET

J 5.1

THE CLOSED-LOOP CONTROL SYSTEM CONTROL MODES INCLUDING THEIR OPERATION AND CHARACTERISTICS

Closed loop control systems, called "servos," are designed to detect an error and respond to correct that error. The servos discussed to this point were basic servo systems.

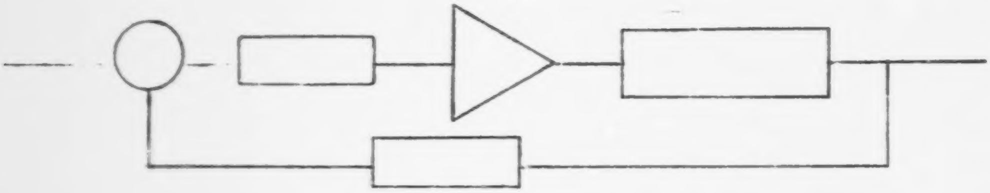


Figure J 5.1-1

Using Figure J 5.1-1, you will notice the addition of a "controller block," which dampens and stabilizes the servo. The form of controller reaction to an error signal is an indication of control mode. Researchers generally agree there are five control modes used to control servo systems:

1. On-Off control
2. Proportional control
3. Proportional plus integral control
4. Proportional plus derivative control
5. Proportional plus integral plus derivative control.

The control modes are listed from simplest to complex. Each mode will respond to an error signal from the comparator, the main differences among them being accuracy and speed of response.

The "On-Off" control is the simplest control because it only has two conditions--either on or off with no in-between. It is sometimes referred to as the "two-position" or "bang-bang" control. An example of an On-Off control is the thermostat used to control the furnace in a home. The thermostat electrically controls a solenoid valve, which controls the gas valve. The thermostat is used to measure and set room temperature; if the temperature is too low, the thermostat turns on the furnace. The furnace will remain ON until the room warms up to the setting on the thermostat, when it will turn OFF. However, even though the furnace turns off, there is still a rise in the temperature because of the heat build-up in the furnace. As the heat is dissipated from the furnace, the room temperature will begin to decrease and may fall well below the preset level, which means the room will get colder before the furnace turns on again. Even though the On-Off control is simple and inexpensive, its lack of precision has prompted the development of more sophisticated control modes.

Unlike the On-Off control, the "proportional" control has a range of outputs which are a percentage of the on-off state of operation. For example, if you replace the on-off thermostat with a thermostat that has a variable output voltage proportional to room temperature and the solenoid valve with a servo valve, you will have a proportional control system. Setting the room temperature at seventy (70) degrees and the servo valve at its fifty (50) percent open point, any variation in room temperature will vary the servo valve opening. The servo valve will open or close a percentage of its full open or full closed positions. Hence the output from the servo valve is a percentage, or portion, of the input from the thermostat.

Proportional control may also experience oscillations similar to those of the On-Off control; however, they are controllable. The percentage of valve opening to temperature is known as the "proportional band." If the band is small, then oscillations will occur. By increasing the proportional band width, there are more valve positions for temperature points, so the oscillations will be eliminated or held at a minimum. These oscillations are referred to as "overshoots," which occur when the valve changes with temperature changes. What this means is, when the temperature changes, the servo valve changes to allow gas to the furnace to heat the room back up to the preset temperature. In proportional control, the reaction time (response time) is rapid. If the proportional band is narrow, the rapid response time can cause the servo valve to oscillate and eventually, these oscillations will stop, unlike the On-Off control. Properly adjusted, the proportional band is large, with a slower response time and no oscillations. The major advantage of the proportional control over the On-Off control is that the snap-action oscillations do not occur; therefore operation is much smoother and more stable, but it introduces a permanent offset in measurement. This offset is not useful in most systems; therefore a better-suited control for processing would be a "proportional plus integral control."

To understand the proportional plus integral control (PI), you must understand the concept of an "integrator." Figure J 5.1-2 shows an integrator, with the input applied to the resistor and the output taken across the capacitor. Initially, the capacitor is discharged with no difference in potential between the capacitor plates. When an input voltage is applied to the resistor, current begins to flow and the capacitor begins to charge. Current will continue to flow until the charge on the capacitor equals the input voltage. When the capacitor charge is equal to the input, there is no potential difference (zero volts measured across the resistor).

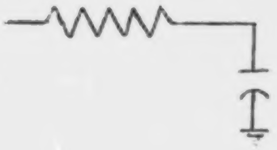


Figure J 5.1-2

With the integrator now connected to a proportional control system, the integrators "reset rate" will reduce the "error signal," or "offset" to zero. Reset rate is the inverse of the capacitor time constant. A large capacitor time constant results in a low reset rate; it means the response time is long for the proportional control. A small or short capacitor time constant results in a high reset rate and response time is short. Since proportional control controls the oscillations, the proportional plus integral will also control the offset prominent in proportional control. Ideally, in PI control there are no oscillations or offsets, and it is effective in most control processes; however, it is not adequate for all situations. It is not sufficient where the load changes very rapidly, or there is a long time lag between the input and the response for the correction of the error. This time lag can be eliminated by the use of a derivative control or differential control with the proportional control system.

The "proportional plus derivative control" is a popular process used in servo control systems; derivative control can also be referred to as "rate control." The derivative amplifier added to the proportional control responds to the rate of change of the error signal to eliminate any stability problems that may occur. The discussion of a proportional plus derivative control system (PD) is similar to the information covered when defining a good closed-loop control system. The PD system must be critically damped to eliminate overshoots and oscillations which cause instability. To understand "derivative control," you must understand "differentiator," shown in Figure J 5.1-3.

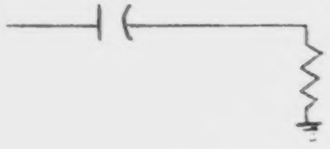


Figure J 5.1-3

If the input to the differentiator is DC, the capacitor blocks the signal and the output will be grounded. If the input is AC, the capacitor will pass the signal and the output will be taken across the resistor as a differentiated output. This differentiated output is referred to as a "time rate of change of the error." Using a rate control, the derivative control overcorrects for the error in order to null (zero) the error. This rate time variable of derivative control is very complicated from a mathematical approach. Simply, rate time is the amount of time the PD control is looking ahead into the future, anticipating the overcorrection needed to control or null the error. The proportional plus derivative control cannot control the offset that was prevalent in the proportional control. To control the offset and stability, a proportional plus integral plus derivative control (PID) was developed which has the advantages of all three types of controls.

The type of control mode to be used may be determined by its application.

ACTIVITY SHEET

J 5.2

THE CLOSED-LOOP CONTROL SYSTEM CONTROL MODES INCLUDING THEIR OPERATION AND CHARACTERISTICS

1. On-Off control is highly accurate and stable.

   a. True
   b. False

2. What is the primary disadvantage of On-Off control compared to other control modes?

3. What are the advantages of the On-Off control over the other modes?

4. Generally, when is the On-Off control mode acceptable for use?

5. Using proportional control, should the proportional band be wide or narrow for a stronger reaction to the error signal?

6. Explain the permanent offset in proportional control.

7. Integral control is also called _______________ control.

8. What is/are the advantage(s) of proportional plus integral over proportional control?

9. With the integral time constant long, does the proportional plus integral correct the offset faster or slower?

10. Derivative control is also called _____________control.

11. Does the proportional plus derivative control improve stability or accuracy?

12. What is/are the advantage(s) of the proportional plus integral plus derivative control over other control modes?

ACTIVITY SHEET J 5.2

ANSWER SHEET

1. B

2. Permanent oscillations

3. It is inexpensive, reliable, simple, and easy to adjust and maintain.

4. Where accuracy and stability are not important; where oscillations do not impair the function of the system.

5. Wide; a narrow band reacts faster, but it also will oscillate; on the other hand, the wider the band, the slower the response, but there are no oscillations.

6. Proportional control, to be effective, needs to have a narrow proportional band. When the band is narrow, there is the possibility of oscillation; however, the proportional control is used on systems that move slowly, which will reduce the oscillations. A slow-moving system means its control has been adjusted to a point where the output will never equal the input; therefore, a constant offset.

7. Reset

8. Proportional control eliminates the oscillations found in On-Off control; the integrator eliminates the offset found in the proportional control, and it can be used on loads with large and rapid changes.

9. Slower

10. Rate

11. Stability; the derivative control only stabilizes the rapid changes of the load; it cannot, however, remove the offset of the proportional control.

12. The proportional control eliminates the oscillations associated with the "bang-bang" response of the On-Off control. Using the proportional control has the disadvantage of producing an offset in the output. To eliminate this offset, the integrator is added to the proportional control. However, this does not completely remove the error (null the error signal). Therefore, the derivative control is added to make a proportional plus integral plus derivative to incorporate the advantages of the three types of proportional control systems.

ELECTRONICS

CONTROL SYSTEMS AND DEVICES

J 6: THE SCR

TASK:	Explain the operation of a Silicon-Controlled Rectifier (SCR).
PURPOSE:	An electronics technician is required to maintain electrical as well as electronic control circuits. A thyristor, gate-controlled rectifier, SCR, is used in controlling load current for various DC loads. The knowledge gained from this lesson guide will enhance the technician's ability to maintain control circuits.
OBJECTIVE:	Given a list of statements, select the statement which best identifies the operating characteristics of a silicon-controlled rectifier. To master this task, you must score 90% on a written examination.

ESTIMATED CLASS TIME: 4 HOURS

THE SCR

LEARNING STEPS

J 6

READ: Information Sheet J 6.1 on "The Operation of Silicon-Controlled Rectifier (SCR)."

READ: Information on the operation of a silicon-controlled rectifier (SCR) from the following resource list.

COMPLETE: Activity Sheet J 6.2 on the operation of a silicon-controlled rectifier (SCR) controlling a resistive load.

COMPLETE: Written Examination J 6.3 on the operation of a silicon-controlled rectifier (SCR).

2025

THE SCR

RESOURCES

1. Timothy J. Maloney, INDUSTRIAL SOLID-STATE ELECTRONICS DEVICES AND SYSTEMS, (Prentice-Hall, Inc., 1986). Second Edition.
2. Albert P. Malvino, ELECTRONIC PRINCIPLES, (McGraw-Hill, Inc., 1984). 3rd Edition.

INFORMATION SHEET

J 6.1

OPERATION OF A SILICON-CONTROLLED RECTIFIER

A silicon-controlled rectifier is a three-terminal, four-layer, specialized type of semiconductor device used to control large currents to a load. An SCR is also known as a thyristor, gate-controlled rectifier, and a high power, fast-acting DC switch. SCR's became prominent in the early 1960's for use in high power DC circuits to replace rheostats and large variable transformers. Figure J 6.1-1 shows the schematic symbol for an SCR.

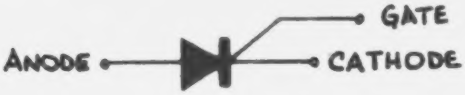
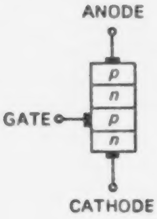
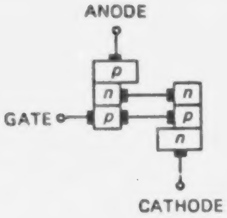


Figure J 6.1-1

The operation of a basic SCR is explained by using equivalent circuits. Figure J 6.1-2 shows the layer diagram, Figure J 6.1-3 shows the transistor form, and Figure J 6.1-4 shows the 2 transistors connected in series. Figure J 6.1-4 as an equivalent circuit, is useful in explaining the actual operation of an SCR.





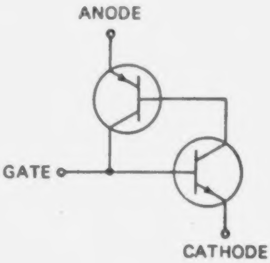


Figure J 6.1-2

Figure J 6.1-3

Figure J 6.1-4

In Figure J 6.1-4, 2 bipolar transistors, an NPN and a PNP are connected in series to form a latching circuit. Q1 is a PNP and Q2 is an NPN transistor; both are connected as common emitter (CE) electronic switches. The collector of Q2 is the base of Q1, and the collector of Q1 is the base of Q2. "Quiescently," with no input, the anode is connected to B+ and the cathode is connected to ground. Current flow in an SCR is from cathode to anode (electron theory) or anode to cathode (conventional theory), when the device is turned on. The gate electrode controls the current flow in an SCR with a trigger or sinewave input to the base of Q2.

A positive going trigger applied to the base of transistor Q2 turns on Q2 and its collector goes low. A low on the collector, which is the base of Q1, turns on Q1. With Q1 on, its collector goes high, and it is the base of Q2. The high from Q1's collector keeps Q2 on and Q2's collector low keeps Q1 turned on, thus forming a latching circuit within a single component. Once an SCR is gated on, it no longer needs a gate input to remain in the "on" state.

To turn off an SCR then, an external signal or switching circuit is required. The most common method of turning off an SCR is to "reverse bias" the anode to cathode by opening the power supply connection. A second method is to use a shorting switch between the anode and cathode, placing them at the same potential. (However, this is not a standard method of turning off an SCR.) The third method of turning off an SCR is by using an AC input to the gate. During the positive half-cycle, the SCR is turned on, and during the negative half-cycle, it is turned off. The on and off conditions will be further explained by covering some of the characteristics of an SCR: the firing delay angle, conduction angle, gate trigger current, holding current, and forward ON-state voltage. See Figure J 6.1-4.

Figure J 6.1-5 shows an input sinewave, the firing delay and conduction angle waveforms. The firing delay angle is the number of degrees during the input before the SCR is gated ON. This means there is a period of time that the voltage on the gate is not positive enough to turn on the SCR. Since an SCR consists of P/N junctions, there is a minimum barrier potential that must be reached before the P/N junction is forward biased. The firing delay angle is also adjustable by controlling the amount of gate trigger current; this is normally a resistive circuit using a fixed and variable resistor (potentiometer). Once the current is sufficient to turn on the SCR, the firing delay angle ends and the conduction angle begins. The conduction and firing delay angles must total 180 degrees when added together, as shown in Figure J 6.1-5. Therefore, if the firing delay angle is 45 degrees, the conduction angle is 135 degrees, and there is no conduction during the negative half-cycle. See Figure J 6.1-5.

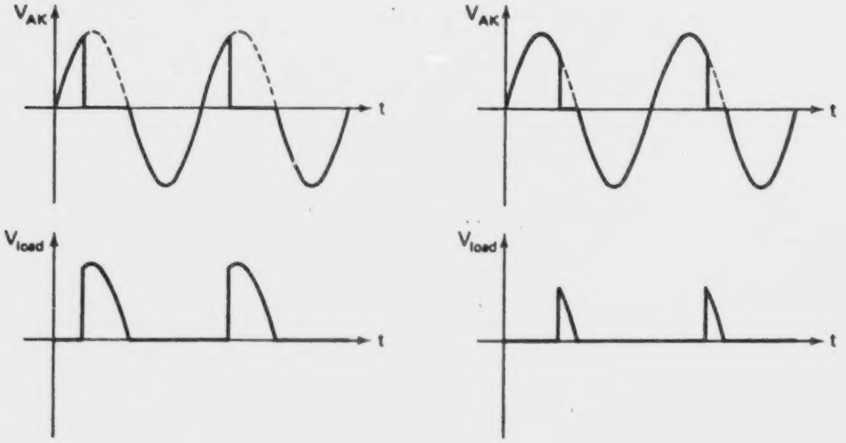


Figure J 6.1-5

Since the firing delay angle controls the amount of time the SCR is ON, it also controls what is referred to as the "average load current." When the SCR is off, the instantaneous voltage felt across the SCR is the supply voltage, which is indicative of an open switch. If the supply is dropped across the SCR, there is no voltage drop across the load and therefore, there is no load current. When the SCR is triggered on, the voltage, anode to cathode, is zero (0) and all supply voltage is felt across the load with current flowing through the load and the closed SCR switch. The trigger voltage is also known as the "forward blocking voltage" or "forward ON-state voltage." The blocking voltage is proportional to the firing delay angle shown in Figure J 6.1-5, the sinewave beginning of the waveform is the amount of voltage applied, and the sharp trailing edge occurs when the SCR is triggered ON. As mentioned earlier, the firing delay angle can be adjusted by using a resistive network in the gate circuit which controls the amount of gate triggering current. The firing delay angle adjustment also controls the amount of load current; the smaller the delay angle, the larger the conduction angle, resulting in more load current.

As mentioned in the operation of the equivalent circuit, once the SCR is fired, it is not necessary to maintain a gate current because of the internal positive feedback that keeps the SCR ON. This positive feedback is referred to as the "holding current," which is a small amount of current (50 mA) that will hold the SCR in the ON-state. If the current between the anode and cathode falls below the holding current, the SCR will reverse bias and turn off; and once it is in the OFF-state, a gate input will be necessary to turn it back on.

Figure J 6.1-6 shows a typical gate control circuit using a resistive network. If R2 is adjusted for maximum resistance, more input voltage will be required for sufficient gate current to fire the SCR. This means the firing delay angle will be large and the conduction angle will be small, resulting in low load current. The opposite will occur if R2 is adjusted for minimum resistance; less supply voltage, shorter firing delay angle, longer conduction angle, resulting in more load current. With the voltage and current characteristics already discussed, OFF-state current is zero (0) and ON-state voltage is zero (0); therefore an SCR is economical because of its low power dissipation and its small physical size. See Figure J 6.1-6.

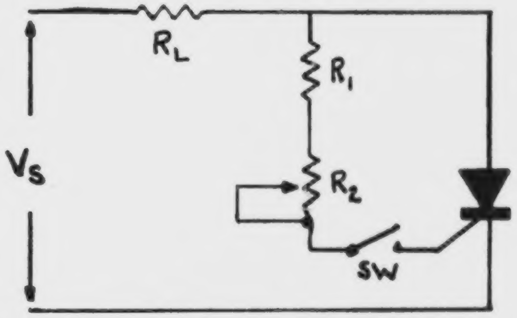


Figure J 6.1-6

The major disadvantages of SCR's are temperature dependence and inconsistent firing points; the SCR will fire sooner when the temperature increases. This means the simple resistive circuit discussed is not the best method for controlling gate current. To ensure that the SCR fires at the same forward blocking voltage consistently, a "break over" device is added in the gate circuit. A four-layer diode is used as a break over device because it is independent of temperature changes. The four-layer diode is connected in the resistive circuit along with a capacitor, shown in Figure J 6.1-7, to hold the break over and the forward blocking voltage constant. The capacitor will charge to the forward blocking voltage, which fires the four-layer diode, which causes a burst of current to be felt on the gate of the SCR, providing a consistent firing point. There are other components that can be used as break over devices with similar characteristics to the four-layer diode. See Figure J 6.1-7.

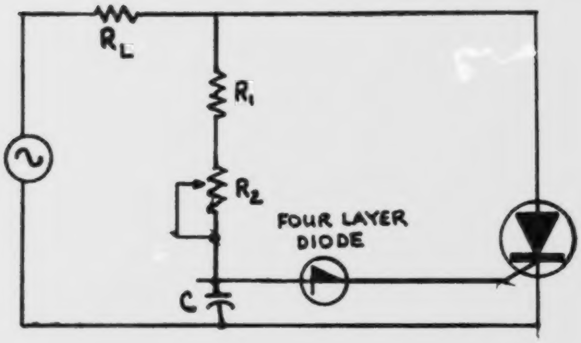

R_L
R_1
R_2
FOUR LAYER DIODE
C

Figure J 6.1-7

ACTIVITY SHEET

J 6.2

THE SCR

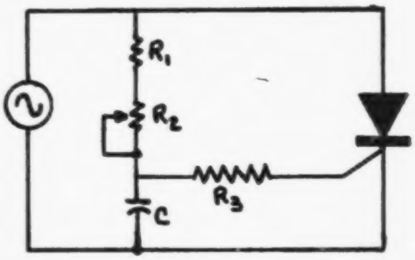
OBJECTIVES:

1. Verify the operation of an SCR that is driving a resistive load.
2. Observe the waveforms and electrical characteristics of an SCR, T1C106B or equivalent.

TOOLS: Oscilloscope (dual trace), VOM.

PROCEDURE:

1. Construct the gate control circuit as shown in the figure below:



a. R1=47KΩ, R2=500KΩ pot., R3=1KΩ, and C=.1 μF. RL=100Ω, 100 W.

_____ Instructor check that circuit is connected correctly before turning on power.

2. Ensure that the 115 Vac source is isolated from ground.
3. Using the figures from the Information Sheet J 6.1-1, measure and record the minimum and maximum firing delay angles, with the oscilloscope connected across the load resistor.
4. Adjust the oscilloscope for measuring two waveforms.
5. Connect the second channel of the oscilloscope across the SCR.
6. Adjust the 500KΩ pot for an increased firing delay angle.
7. Draw the load waveform and the SCR waveform.

ACTIVITY SHEET J 6.2 CONT'D.

8. Compare the two waveforms.
Do they agree with the theory you have covered? ______

9. Connect the oscilloscope across the gate 1K Ω resistor. Using Ohm's Law, measure the gate current needed to fire the SCR.
____

10. Turn off the power to the circuit.

11. Before disconnecting, have instructor check your readings for correctness.

_____ YES _____ NO

ACTIVITY SHEET J 6.2

ANSWER SHEET

Answers to this activity sheet will depend on the tolerance of the resistors being used and the SCR used.

It is suggested that the instructor perform this Activity Sheet prior to the student's making any connections.

EXAM J 6.3

DIRECTIONS:

The purpose of this examination is to determine whether or not you have understood the information on Silicon-Controlled Rectifiers. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Shade in the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on the answer sheet. Use a #2 pencil to mark you answers. DO NOT WRITE ON THIS TEST!!!! To master this examination, you must score 90% on the task being tested.

EXAM J 6.3 CONT'D.

1. An SCR is a four-terminal, three-layer specialized type of semiconductor device.

   A. True
   B. False

2. An equivalent circuit for an SCR is a two-transistor circuit with the transistors connected in series.

   A. True
   B. False

3. To turn off an SCR, an external signal or switching circuit is required.

   A. True
   B. False

4. Once an SCR is gated on, the gate input is no longer needed.

   A. True
   B. False

5. An SCR is triggered to the ON-state by the negative half cycle of an AC input signal.

   A. True
   B. False

6. The firing delay angle represents the time the SCR is in the ON-state.

   A. True
   B. False

7. If the firing delay angle is 45 degrees, the conduction angle is _____________ degrees.

   A. 45
   B. 125
   C. 15
   D. 135

8. The trigger voltage is also known as the ______________ .

   A. break over device
   B. forward ON-state voltage
   C. holding current
   D. conduction angle

9. A break over device is used to __________________ .

   A. ensure that the SCR fires consistently
   B. increase the conduction angle
   C. vary the internal positive feedback
   D. reverse bias the SCR

10. Holding current is typically __________________ .

   A. 10 mA
   B. 50 mA
   C. 20 mA
   D. 15 mA

EXAM KEY J 6.3

1. B
2. A
3. A
4. A
5. B
6. B
7. D
8. B
9. A
10. B

ELECTRONICS

CONTROL SYSTEMS AND DEVICES

J 7: THE UNIJUNCTION TRANSISTOR (UJT)

TASK:	Explain the operation of a Unijunction Transistor (UJT).
PURPOSE:	A unijunction transistor (UJT) is a break-over switching device used in the gate control circuits for SCR's TRIAC's (see Tasks). The knowledge gained from this lesson guide will enhance the technician's ability to maintain control circuits.
OBJECTIVE:	Given a list of statements, you will select the statement which best identifies the operating characteristics of a unijunction transistor (UJT). To master this task, you must score 90% on a written examination.

ESTIMATED CLASS TIME: 4 HOURS

THE UJT

LEARNING STEPS

J 7

READ: Information Sheet J 7.1 on "The Operation of a Unijunction Transistor (UJT)."

READ: Information on the operation of a unijunction transistor from the following resource list.

COMPLETE: Activity Sheet J 7.2 on the operation of a unijunction transistor (UJT) used as a break over switching device.

COMPLETE: Written Examination J 7.3 on the operation of a unijunction transistor (UJT).

THE UJT

RESOURCES

1. Timothy J. Maloney, INDUSTRIAL SOLID-STATE ELECTRONICS DEVICES AND SYSTEMS, (Prentice-Hall, Inc., 1986). Second Edition.

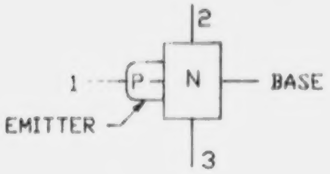
2. Albert P. Malvino, ELECTRONIC PRINCIPLES, (McGraw-Hill, Inc., 1984). 3rd Edition.

INFORMATION SHEET

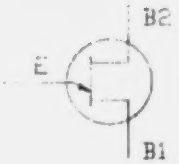
J 7.1

OPERATION OF A UNIJUNCTION TRANSISTOR

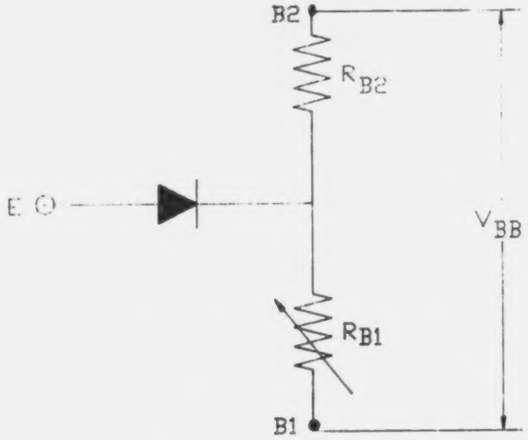
A unijunction transistor (UJT) is a three-terminal semiconductor device, sometimes referred to as a "double based diode." Characteristically, a UJT has (1) a stable triggering voltage, (2) a very low value of firing current, (3) a negative resistance characteristic, and (4) a high pulse current capability. The block diagram of a UJT in Figure J 7.1-1 shows the leads, type of semiconductor material used (doping), and the names of the elements. Figure J 7.1-2 shows the schematic symbol and Figure J 7.1-3 shows an equivalent circuit. Figure J 7.1-3 is the electrical equivalent circuit used to describe the operating characteristics of a UJT.



J 7.1-1



J 7.1-2



J 7.1-3

To fire or turn on a UJT, the emitter to Base 1 must be forward biased. R_{B1} is shown as a variable resistance in a voltage divider consisting of R_{B1} and R_{B2}. In normal operation, B2 is connected to a positive potential and B1 is grounded. When the voltage between the emitter and B2 is less than the "peak voltage" (Vp), the UJT is reverse biased and no current flows through the emitter diode. The peak voltage is a percentage (intrinsic standoff ratio) of the voltage divider voltage (V_{BB}) plus the P/N junction voltage of +0.7V. When the emitter to Base 1 voltage exceeds Vp, the diode is forward biased and the circuit between the emitter and Base 1 is ideally a short circuit, and a short-lived burst of current flows from one terminal to another.

Since the current is short-lived, the UJT reverts back to the "off" state very quickly. Figure J 7.1-4 depicts the current and voltage characteristics of a UJT. See Figure J 7.1-4.

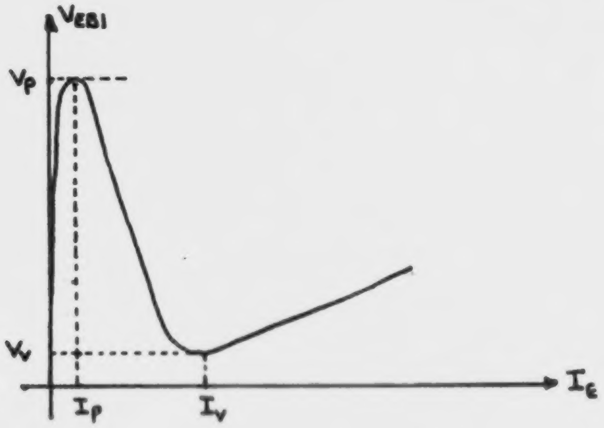


Figure J 7.1-4

When the voltage between the emitter and Base 1 rises to Vp, emitter current begins to flow and the UJT "breaks over" to a small voltage between the emitter and Base 1 terminals. This "valley voltage" (Vv) is reached because of the rapid increase of current in the region. When the emitter voltage drops below the value of the valley voltage and the minimum current, "valley current" (Iv), is not maintained, the UJT returns to the OFF state and the emitter voltage must rise again to the peak voltage in order to fire.

A UJT is very useful in the gate triggering circuits for SCR's. However, the intrinsic standoff ratio characteristic is fixed by the manufacturer. A programmable UJT (PUT) was developed to overcome the limits of the standard UJT. A PUT differs from the UJT in that the intrinsic standoff ratio can be set to a specific value. Remember, the intrinsic standoff ratio controls the value of Vp, which is the "break over" or firing point of the UJT.

INFORMATION SHEET J 7.1 CONT'D.

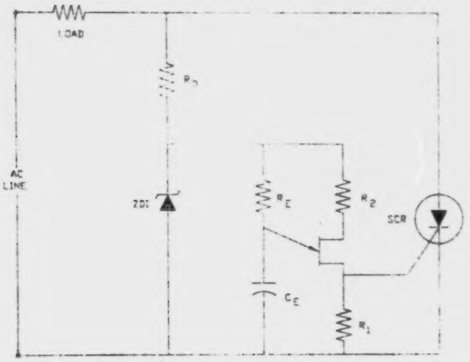


Figure J 7.1-5

A UJT used to control the firing of an SCR is shown in Figure J 7.1-5 above. Since an SCR is a DC switch which converts AC to DC, a capacitor is used in the emitter circuit to charge to the peak voltage. The variable resistance connected in series with the capacitor controls the rate at which the capacitor charges, controlling the firing of the UJT as well as the SCR. Once the UJT fires, when the capacitor reaches the peak voltage and current flows between the emitter and Base 1, a voltage pulse is felt across the resistor R_1. The positive going pulse across R_1 fires the SCR, allowing load current to flow.

ACTIVITY SHEET

J 7.2

CONTROL DEVICES: UNIJUNCTION TRANSISTOR

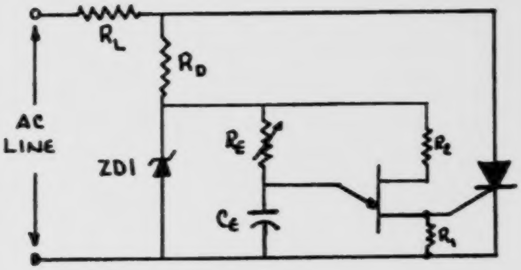
OBJECTIVES:

1. Verify the operation of a UJT used in the gate circuit of an SCR that is driving a resistive load.
2. Observe the waveforms and electrical characteristics of a UJT, 2N4947, using an SCR, T1C106B or equivalent.

TOOLS: Oscilloscope (dual trace), VOM.

PROCEDURE:

1. Construct the gate control circuit as shown in the figure below.



a. R1=100Ω ; RE=100KΩ pot.; R2=1KΩ ; CE=0.068 μF; RL=100Ω , 100W; RD=2.2KΩ , 5W; ZD1=20V

_____Instructor check that circuit is connected correctly before turning on power.

2. Ensure that the 115 Vac source is isolated from ground.
3. Using the oscilloscope, observe the following waveforms:
   - a. Capacitor voltage, V
   - b. Voltage across R_1
   - c. Voltage across the SCR, V
   - d. Voltage across the load, V
4. Do the waveforms observed look like what you expected?

______ YES ______ NO

ACTIVITY SHEET J 7.2 CONT'D.

5. Turn off the power to the circuit.

6. Before disconnecting, have instructor check your readings for correctness.

ACTIVITY SHEET J 7.2

ANSWER SHEET

Answers to this activity sheet will depend on the tolerance of the resistors, the UJT and the SCR being used.

It is suggested the instructor perform this activity sheet prior to the student's making any connections. The student should use the instructor's performance as a demonstration.

EXAM J 7.3

DIRECTIONS:

The purpose of this examination is to determine whether or not you have understood the information on Unijunction Transistors. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Shade in the letter associated with that choice (A, B, C, D, or E) in the numbered blank space on the answer sheet. Use a #2 pencil to mark your answers. DO NOT WRITE ON THIS TEST!!!!To master this examination you must score 90% on the task being tested.

EXAM J 7.3 CONT'D.

1. A UJT is a three-terminal specialized type of semiconductor device.

   A. True
   B. False

2. An equivalent circuit for a UJT is a two-transistor circuit with the transistors connected in series.

   A. True
   B. False

3. To turn on a UJT, the emitter voltage must exceed the peak voltage.

   A. True
   B. False

4. Once a UJT is turned on, it remains on until power is removed.

   A. True
   B. False

5. A UJT is effective in controlling the gate firing point of a thyristor such as an SCR.

   A. True
   B. False

6. The firing delay angle of an SCR is controlled by a UJT.

   A. True
   B. False

7. The voltage between the emitter and Base 1 of the UJT must be below the valley voltage to turn on the UJT.

   A. True
   B. False

8. The intrinsic standoff ratio is used to determine the peak voltage.

   A. True
   B. False

9. UJT current flow is a short-lived pulse.

   A. True
   B. False

10. A UJT break over device is used to _______________.

   A. ensure that the SCR fires consistently.
   B. increase the conduction angle.
   C. vary the internal positive feedback.
   D. reverse bias the SCR.

EXAM KEY J 7.3

1. A
2. B
3. A
4. B
5. A
6. A
7. B
8. A
9. A
10. A

ELECTRONICS

CONTROL SYSTEMS AND DEVICES

J 8: THE TRIAC

TASK: Explain the operation of a TRIAC.

PURPOSE: An electronics technician is required to maintain electrical as well as electronic control circuits. A gate-controlled bilateral triode switch, TRIAC, is used in controlling the current for various AC loads. The knowledge gained from this lesson guide will enhance the technician's ability to maintain control circuits.

OBJECTIVE: Given a list of statements, you will select the statement which best identifies the operating characteristics of a TRIAC. To master this task you must score 90% on a written examination.

ESTIMATED CLASS TIME: 4 HOURS

THE TRIAC

LEARNING STEPS

J 8

READ: Information Sheet J 8.1 on "The Operation of a TRIAC."

READ: Information on the operation of a TRIAC from the following resource list.

COMPLETE: Activity Sheet J 8.2 on the "Operation of a TRIAC Controlling a Resistive Load."

COMPLETE: Written Examination J 8.3 on the operation of a TRIAC.

THE TRIAC

RESOURCES

1. Timothy J. Maloney, INDUSTRIAL SOLID-STATE ELECTRONICS DEVICES AND SYSTEMS, (Prentice-Hall, Inc., 1986). Second Edition.

2. Albert P. Malvino, ELECTRONIC PRINCIPLES, (McGraw-Hill, Inc., 1984). 3rd Edition.

INFORMATION SHEET

J 8.1

OPERATION OF A TRIAC

A TRIAC has various industrial and electronic circuit applications for the control of alternating current to a load. A triac's operation is similar to that of an SCR except that a triac can conduct in either direction. The schematic symbol is shown in Figure J 8.1-1; notice the similarity to the SCR. The triac consists of a gate and two main terminals. The "main terminals" are labeled this way because they can function as an anode or cathode, dependent on the input voltage phase. The phase or polarity of the AC input will determine if MT1 or MT2 functions as the anode or cathode. The phase or polarity of the AC also controls the gate terminal, which controls the direction of current flow through the triac.

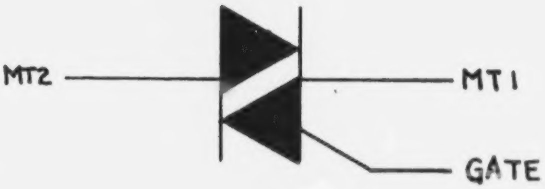


Figure J 8.1-1

Figure J 8.1-2 illustrates the normal connection of a triac to the source and the load device. For improved operation, a gate triggering circuit is employed to ensure a specific and consistent firing point; the gate control circuit may use a UJT as discussed in the previous topic.

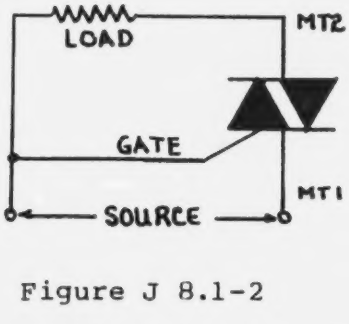


Figure J 8.1-2

The main operating difference between the SCR and TRIAC is the gate circuit. In an SCR circuit the gate trigger is no longer needed, once the device is gated on. In a TRIAC circuit, the gate input is required to sustain current flow to the load device. The waveforms will be the same as those for an SCR, and they will occur for a complete sinewave input (360°). The firing delay angle, gate trigger current and holding current characteristics are the same for both devices.

A brief explanation of the operation of a TRIAC, using Figure J 8.1-2 is as follows:

> With MT2 positive in respect to MT1, and the gate positive in respect to MT1, current will flow heavily from MT2 to MT1, using conventional current flow theory. When MT1 is positive in respect to MT2 and the gate is negative in respect to MT1, current will flow heavily from MT1 to MT2. The starting point for conduction during each half-cycle is determined by the amount of gate voltage applied.

ACTIVITY SHEET

J 8.2

OPERATION OF A TRIAC THAT IS DRIVING A RESISTIVE LOAD

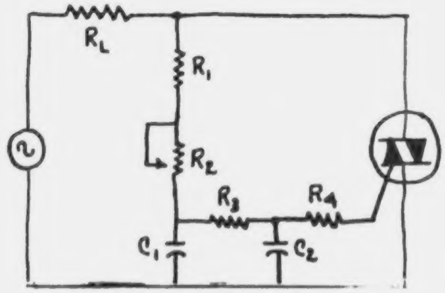
OBJECTIVES:

1. Verify the operation of a TRIAC that is driving a resistive load.
2. Observe the waveforms and electrical characteristics of a TRIAC, 40485 or equivalent.

TOOLS: Oscilloscope (dual trace), VOM.

PROCEDURE:

1. Construct the gate control circuit as shown in the figure below:



a. R1=10KΩ ; R2=200KΩ pot.; R3=33KΩ ; R4=100Ω C1=0.22 μF; C2=0.22 μF; RL=100Ω , 100W

_____Instructor check that circuit is connected correctly before turning on power.

2. Ensure the 115 Vac source is isolated from ground.

3. Measure and record the minimum and maximum firing delay angles, with the oscilloscope connected across the load resistor.

4. Adjust the oscilloscope for measuring two waveforms.

ACTIVITY SHEET J 8.2 CONT'D.

5. Connect the second channel of the oscilloscope across the TRIAC.

6. Adjust the 200K Ω pot for the range of the firing delay angles.

7. Draw the load waveform and the TRIAC waveform.

8. Are the firing delay angles equal for both half cycles?

_____ YES _____ NO

9. Connect the o'scope across the gate resistor R_4. Using Ohm's Law, measure the gate current needed to fire the TRIAC. __________

10. Are the waveforms and currents what you expected to observe from the theory provided in the SCR and TRIAC information sheets?

_____ YES _____ NO

11. Turn off the power to the circuit.

12. Before disconnecting, have instructor check your readings for correctness.

_____ YES _____ NO

ACTIVITY SHEET J 8.2

ANSWER SHEET

Answers to this activity sheet will depend on the tolerance of the resistors being used and the TRIAC used.

It is suggested the instructor perform this activity sheet as a demonstration prior to the student's making any connections.

EXAM J 8.3

DIRECTIONS:

The purpose of this examination is to determine whether or not you have understood the information on TRIAC's. Each of the questions or incomplete statements is followed by several words, phrases, or a series of numbers. Choose the one which best answers the question or completes the statement correctly. Shade in the letter associated with that choice (A,B, C, D, or E) in the numbered blank space on the answer sheet. Use a #2 pencil to mark your answers. DO NOT WRITE ON THIS TEST!!!!To master this examination you must score 90% on the task being tested.

EXAM J 8.3 CONT'D.

1. A TRIAC is a three-terminal, four-layer device that is similar in operation to an SCR.

   A. True
   B. False

2. A TRIAC provides DC current to the load device.

   A. True
   B. False

3. A gate control signal must be present at all times to keep the TRIAC in the "on" condition.

   A. True
   B. False

4. Once a TRIAC is gated on, the gate input is no longer needed.

   A. True
   B. False

5. A TRIAC controls the average _________ current through a load.

   A. AC
   B. DC

6. The firing delay angle represents the time the TRIAC is in the ON-state.

   A. True
   B. False

7. If the firing delay angle is 45 degrees, the conduction angles are _________ and __________ degrees.

   A. 45, 90
   B. 125, 305
   C. 15, 195
   D. 135, 225

8. The _____ or _____ of the AC input controls the direction of current flow through the TRIAC.

   A. amplitude, frequency
   B. phase, frequency
   C. amplitude, polarity
   D. phase, polarity

9. A break over device is used to ____________ .

   A. ensure the TRIAC fires consistently.
   B. increase the conduction angle.
   C. vary the internal positive feedback
   D. reverse bias the TRIAC

10. If the conduction angles are 60 degrees for both half cycles, the firing delay angles occur at ______ and _______ degrees for the positive and negative half-cycles.

   A. 120, 300
   B. 60, 240
   C. 0, 180
   D. 30, 90

EXAM J 8.3

ANSWER SHEET

1. A
2. B
3. A
4. B
5. A
6. B
7. D
8. D
9. A
10. A

APPENDIX

A

MATH/SCIENCE CONCEPT ANALYSIS

INTRODUCTION

OVERVIEW

This appendix presents an analysis of the science and mathematics concepts considered pre-requisite or co-requisite to understanding the content of the ELECTRONICS Curriculum. The science and mathematics concepts listed are considered those concepts that can be taught or should be taught as part of the Electronics Curricula. Without a good grasp of the concepts included in this appendix, students are likely to have difficulty understanding the basic concepts of the electronics program. Also included in this appendix is an analysis which identifies many concepts associated with establishing a strong work ethic and developing good communication skills. The concepts produced by this second analysis are also very important to understanding what is necessary to function effectively in the electronics field.

The Concept List for the Electronics Curriculum is organized around Content Areas, Tasks, and Objectives. The concept analysis was accomplished by identifying the science, mathematics, work ethic, and communications concepts, principles, and skills that are associated with the group of objectives listed for each of the electronics task. There was no attempt to establish a one-to-one correspondence between tasks and concepts because many of the tasks require an understanding of the same concepts. In addition, the concepts are more associated with the Area than they are with the individual tasks.

USING THE LIST

To use the concept lists produced by the analysis, you will first need to identify the Electronics "Area" of interest. Having identified the Task, you will find four groups of concepts under the subheading of Science, Mathematics, Work Ethic, and Communications. The concepts, principles, and skills listed under these subheadings need to be understood in order for students to understand the electronics content associated with the Area and the specific task.

Once the concepts associated with the task objectives for the Area are known, it is possible to determine what, if any, steps need to be taken to insure that the students understand these concepts. This determination can be made in various ways such as examining students' success in previous course work and devising a system of pre-testing. If students do not understand these basic concepts, it will be necessary to teach the concepts as part of your program. It is important that the students posses knowledge from fields on which some of the electronics content is based as well as understand the content of electronics.

The list of concepts can also be used to help advise school personnel as to the knowledge and skills students should acquire in other areas of the school curriculum in order to do well in Electronics and other curricular areas dealing with major societal problems and concerns about personal living. For example, by demonstrating how often certain science and mathematics concepts appear in the concept lists, it can be illustrated how important it is for the students to have a solid academic background in order to succeed in the Electronics Curriculum. This information and information from other examinations of the concept lists can be used to help shape the nature of the school curriculum and the content of courses in electronics and other fields. Examinations of the concepts lists will also demonstrate the academic status of today's Electronics Curriculum and demonstrate the magnitude of the contribution that the Electronics Curriculum is making to increasing students basic knowledge and skills in science, mathematics, work ethic and communications.

For further information contact Alan Voelker, Ph.D., Department of Curriculum and Instruction, Northern Illinois University, DeKalb, IL 60115.

Task A 1 - Electronics

A.1 TASK: Identify various sources of electricity.

Science: system, subsystem, sources of energy, energy conversion, energy conservation, types of energy storage, sources of electricity, scientific careers/career education, scientific vocabulary, atom, atomic bonding, negative ions, positive ions, charge, compound, crystal, electron, element, impurity, ion, molecule, negative, neutron, nucleus, valence ring, valence electronics, proton, positive, shell.

Communication: vocabulary and terminology necessary to communicate, language development.

A.1.1

Science: systems, concepts, laws, principles, parsimony, variation, multiple use, uses of knowledge, logical thinking, inference, sources of electricity, definition of electricity, definition of electronics, elements, properties of materials, atomic structure, molecular structure, electrical fields, magnetic fields, Bohr Model of the atom, electrical charges, lines of force, attraction, repulsion, atomic orbitals, electronic configurations, valence, ions, stable state, free electrons, conductors, insulators, semiconductors, Coulomb, electron flow, current. Classification, natural, man-made, substance, orbit, speed of light technology, charge, Electromotive force, electron potential, energy, kinetic energy, potential energy, voltage, electric storage systems, chemical reaction, magnetism, electromagnetic field, friction, heat, energy emission, light, photoelectric, pressure, power source, energy transmission, energy transfer, resistance, direct current, alternating current, patterns, symmetry, terminals, load.

Work ethic: spent time developing fundamentals and basics; need to start at the beginning and continue to refine, use correct equipment, use equipment correctly, follow safety precautions, store equipment properly.

Communication: forms of communication, requirements for communication, vocabulary development.

C: read, understand, and find information or gather data from books, manuals, directories, or other documents.

Mathematics: scientific notation, decimal system, powers of then, magnitude, units of measurement. Set, subset.

Task A 2 - Voltage, Current & Resistance

A.2 TASKS: Identify voltage, current and resistance.

Science: variables, identify and control variables, manipulate variables, voltage, current, resistance, interdependence, systems.

Mathematics: ratio and proportion, equations, direct proportion, inverse proportion, construct and interpret graphs, basic arithmetic, manipulate fractions.

Work Ethic: safety, proper care of equipment, organize work.

Communication: record data.

A.2.1

Science: change, interaction, unbalanced, uses of scientific knowledge, technology, Coulomb, circuit, voltage, difference of potential, forces pressure, conductor, electrical storage devices, chemical reaction, construction of electrical devices, solubility, solutions, types of electrolyte, electronegativity, direction of flow, electrical discharge, properties of materials, electromotive force, terminals, frames and points of reference, techniques for gathering data, grounding, electrical grounding, developing models and analogies, identify and control variables, ampere, history of science and technology, theory, change, resistor, ohm current, types of resistors, functions of resistors, construction of circuits and component parts, energy conversion, power, watt, Ohm;s Law, ground potential electron flow theory, polarity, theory, drop voltage.

Mathematics: units of measurement, equivalent systems, estimation, orders of magnitude, scientific notation, rules and conventions, value, units of time, time intervals, ration, micro, macro, formulas, diameter, area, temperature, length, high, low, milli, micro, mega, cross-sectional area, direct proportion, indirect proportions, decimal, percent.

Work ethic: learn basic vocabulary, follow safety rules, follow directions, use of checksheets, identifying appropriate equipment, proper care of equipment, attending to details.

Communication: using conventions and names, naming conventions, uses of symbols, formulating models, uses of prefixes, read, understand, and find information or gather data from books, manuals, directories, or other documents.

Task A 3 - Conductors and Insulators

A.3 TASK: Compute/measure resistance and conductance of conductors and insulators.

Science: compare and contrast, measurement, parameters, circuit, resistance, conductor, insulator, current, conductance, limits/limiting factors.

S: free electrons, properties of materials, valence, valence ring, ohm, interaction, variables, energy, heat, impurity, conductivity, non-conductor, semi-conductor, circuit board, classification, identify and control variables, change, flexible, problem-solving.

Mathematics: basic computations, rate, amount/quantity.

M: compare and contrast, units of measurement, percent, standards, units of measurement, less than, greater than, equal to, inverse proportions, circle, area, increase, decrease, temperature, length, mil, units of measurement, percent, circumference.

Work ethic: proper use of tools and equipment, develop and practice, use correct equipment, follow safety precautions, store equipment properly.

Communication: gather and record data, read, understand, and find information or gather data from books, manuals directories, or other documents.

Task A 4 - DC Electronics

A.4 TASK: Read and interpret color codes.

Science: resistance, forces, friction, free electrons, properties of materials, behavior of materials, career education, uses of knowledge, uses of materials, standards, compare and contract, conductor, insulator, orbitals, valence, orbit, frames of reference, parallel circuits, units of measurement, kinetic energy, energy transfer, disturbance, chemical reactions, corrosion, electronic configurations, resistance, insulators, forces, electron flow, limiting factors, identify and control variables, stability, interaction, semiconductor, dissolve, solubility, classification, chemical bonds, flexibility, change, circuit boards.

Mathematics: serial ordering, ranking, standards of comparison, compare and contrast, ratio, inverse proportion, simple computations, solve equations, areas, diameter, circumference, capacity, length, temperature.

Communication: uses of symbols, formulating definitions, read, understand, and find information or gather data from books, manuals, directories, or other documents.

A.4.1

Science: classification, resistor color codes, resistance, circuit, standards and criteria, properties of materials, systems and components, limitations, limiting factors.

S: identify and control variables.

Mathematics: standards, sequence, order, significant figure multiplication, rate, classification.

M: value, digit, percent.

Work ethic: learn basic conventions and rules, follow directions, practice regularly, checking against standards, paying attention to details, use of appropriate equipment, following safety practices, proper care of equipment.

Communication: use symbols, read and interpret data, record data, construct tables and graphs, developing communication systems.

A.5 TASK: Apply Ohm's Law

Science: identifying unknowns, series circuit, parallel circuit, combination circuits, Ohm's Law, circuit boards, identifying variables, interdependence, analysis and diagnosis, simple circuits, interpreting data.

S: voltage drop, voltage, resistance, volts, amperes, ohms, decimals, Kirchhoffs Laws, circuit branch.

Mathematics: problem-solving, logical thinking, direct proportion, inverse proportion, solving for unknowns, rearranging algebraic equations, units of measurement, basic computations, sums of parts, separating into component parts, part-whole relationships.

M: basic, algebra, total, units of measurement, subscript, milli, range, scale, percent, linear, multiples.

Work ethic: appropriate uses of equipment, construction of equipment (same as earlier - see A 4 list), use correct equipment, follow safety precautions, store equipment properly.

Communication: developing communication systems, preparing appropriate diagrams, reading and interpreting diagrams.

A.6 TASK: Identify and compute electric power.

Science: uses of electricity, work, power, limiting factors, circuits, gather and record data, uses of knowledge, systems and their components, current voltage, resistance, units of measurement, energy conversion, heat transfer, quantity, ampere, voltage, electromotive force, watt, current, Watt's Law, analysis of systems, efficiency, energy consumption, equivalent relationships, energy, joule, conductors, energy loss, power loss, problem-solving, concept of formula, milliwatt, kilowatt, megawatt, kilowatt-hour, kilovolt, voltage, energy, direct current, alternating current, watt, volt, ampere, volts direct current, volts alternating current, ohm, proper use of units (dimensional analysis), generator, power output, heat loss, voltage drop, impedance matching.

S: Ohm's Law, resistor, approximation, filament.

Mathematics: rate, ratio, simple computations, measuring time intervals, length, proportion, direct proportion, solving algebraic equations, replacement with equal quantities (substitution), squares, square roots, simple calculations, problem-solving, solving word problems.

M: value, length, time, units of measurement, milli kilo, mega, percent.

Work ethic: following safety procedures, learning the operating requirements and basic rules, knowing safety requirements, use correct equipment, use equipment correctly, store equipment properly.

Communication: record and arrange data, uses of symbols and abbreviations, uses of prefixes, interpreting figures and diagrams.

Task A 7 - Series Circuits

A.7 TASK: Analyze, construct, and troubleshoot basic series resistive circuits using Ohm's Law and Kirchhoff's Law.

Science: electrical circuits, series circuits, parallel circuits, series-parallel (combination) circuits, components of circuits, systems and subsystems, components of systems, functions of parts, switch, power source voltage drop, Kirchhoff's Law, Ohm's Law, solving for unknowns, constant voltage, power source, resistor, complete circuit, open circuit, short-circuit, uses of scientific knowledge, classification, characteristics of electrical systems.

S: problem-solving, voltage, current, resistance, voltage drop, inference.

Mathematics: arithmetic progression, simple addition, direct and inverse relationships, problem-solving, increase, decrease, part-whole, relationships, expressing concepts as mathematical relationships, summation.

M: percent, units of measurement.

Work ethic: follow safety procedures, learn basic rules and conventions, reviewing and keeping up-to-date, proper use of equipment, maintain equipment, following directions, attending to details, store equipment properly.

Communications: using basic concepts and analogies, interpreting data, read and understand graphs, charts, and tables to obtain factual information.

Task A 8 - Parallel Circuits

A.8 TASK: Analyze, construct, and troubleshoot parallel resistive circuits using Kirchhoff's Law.

Science: circuits, parallel circuits, series circuit, systems, characteristics of systems, uses of circuits, uses of knowledge, problem-solving, solving for unknowns, voltage drop, path of least resistance, divided current, parallel bank, parallel branch, open circuit, closed circuit, short circuit, Kirchhoff's Current Law, source voltage, components of systems, voltage drops, development of concepts, concept verification.

S: conductance, resistance.

Mathematics: drawing to scale, compare and contrast, similar and different, units of measurement, solve simple algebraic equations, constants, part-whole relationships, developing conventions, solving algebraic expressions, developing and using formulas, less than, greater than, equal, inversely proportional.

M: percent, alternate, group, set, subset.

Work ethic: learning fundamentals, proper uses of equipment, proper application, of rules and conventions, following procedures, adhering to safety practices, attending to details, use of appropriate equipment, proper care and storage of equipment.

Communication: using symbols and abbreviations, development of an understanding of codes, interpreting figures.

Task A 9 - Series-parallel Circuits

A.9 TASK: Analyze, construct, and troubleshoot series-parallel resistive circuits using Kirchoff's Law.

Science: circuits, series circuits, parallel, circuits, systems, combination systems, compound circuits, analyzing data, problem-solving, schematic diagrams, uses of basic knowledge, parsimony, data reduction, gathering and recording data, analyzing data, read and interpret diagrams.

Mathematics: part-whole relationships, analyzing data, problem-solving, using step-wise procedures, establishing order, solving component problems, accumulation of answers/solving series problems.

M: combination, constants, rules, percent.

Work ethic: acquiring knowledge base for using techniques and procedures, following rules and procedures, learning fundamentals, proper uses of equipment, proper application of rules and conventions, following procedures, adhering to safety practices, attending to details, use of appropriate equipment, proper care and storage of equipment.

Communication: uses of symbols and drawings, interpret diagrams, read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information.

Task A 10

A.10 TASK: Analyze, construct, and troubleshoot resistive voltage disorder (loaded and unloaded) using Kirchoff's Law.

Science: systems, subsystem, voltage, power source, resistive voltage disorder, input current, circuits, voltage divider circuit, series circuits, parallel circuits, power supply, Ohm's Law, voltage, resistor, forces, load.

S: Kirchoff's Law, problem-solving, resistance, current, change, frames of reference.

Mathematics: part-whole relationships, fractions, directly proportional, inversely proportional, basic equations, percent, percentages, combinations, simple calculations, efficiency.

Work ethic: acquiring knowledge base for using techniques and procedures, following rules and procedures, learning fundamentals, proper uses of equipment, proper application of rules and conventions, following procedures, adhering to safety practices, attending to details, use of appropriate equipment, proper care and storage of equipment, follow instructions or directions in the performance of a specific task.

C: read, understand and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, read and interpret diagrams and figures.

Task A 11

A.11 TASK: Solve basic linear electrical circuits using network theorem analysis.

Science: circuits, series circuits, parallel circuits, Ohm's Law, identify and manipulate variables, laws theories, current, conservation laws, resistance, data reduction, parsimony, voltage sources, power, sources, short circuit, advantages and disadvantages.

S: linear, network theorems, series-parallel circuits, systems, subsystems, complex systems, polarity.

Mathematics: linear equations, theorems, part-whole relationships, proofs, solve algebraic equations, logical thinking, summation, substitution rules, ratio, proportional relationships, simple calculating, constants.

M: set, subset, Kirchoff's current Law, Kirchoff's Voltage Law, Superposition Theorem, theorem, algorithm, Meshequations, Node equations, equal to, sum, greater than, standards, equivalent, equation, subscript.

Work ethic: selecting appropriate equipment, proper use of equipment, acquiring knowledge base for using techniques and procedures, following rules and procedures, learning fundamentals, proper uses of equipment, proper application of rules and conventions, following procedures, adhering to safety practices, attending to details, use of appropriate equipment, proper care and storage of equipment.

Communication: establish rules and conventions, read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand diagrams and figures.

Task A 12

A.12 TASK: Define magnetic properties of circuits and devices.

Science: properties of materials, forces, magnetic field, model development, inference, basic concepts of magnetism, lines of force, conductor, electromagnet, north pole, south pole, molecular structure, polarity, alloy, toroid, magnetism, natural magnet, synthetic magnet, temporary magnet, retentivity, residual magnetism, reluctance, magnetic field, hysteresis, mixtures, uses of knowledge, electrical devices, particule nature of matter, movement of particles, molecular/atom structure, electron configurations, magnitude and direction, energy transfer, classification, behavior of materials, domain theory, ferromagnetic, permanent magnetic, constructing models, current flow.

S: operational definition, current, electron, use of knowledge to construct devices, types of electrical devices, flux lines, electromagnetic field, nucleus, atom, left-hand rule, electrostatic field, identify and manipulate variables, ferromagnetic, substance, components.

Mathematics: area, three-dimensional space, constructing and interpreting graphs.

M: number, circle, increase, decrease, diameter, percent.

Work ethic: selecting appropriate equipment, proper use of equipment, acquiring knowledge base for using techniques and procedures, following rules and procedures, learning fundamentals, proper uses of equipment, proper application of rules and conventions, following procedures, adhering to safety practices, attending to details, use of appropriate equipment, proper care and storage of equipment.

Communication: establishing rules and conventions, using rules and conventions, interpreting diagrams and figures, read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information, read and interpret figures and diagrams, draw diagrams and figures.

Task A 13

A.13 TASK: Analyze, construct, and troubleshoot RC and RL circuits.

Science: circuits, resistance, capacitance, inductance, classification, resistor, inductor, series, current, voltage, vectors, current flow, impedance, inductive reactance, uses of circuits, systems, properties of systems, capacitor, units of measurement, units, charge, discharge, prediction, patterns, variables, limiting factors.

S: problem-solving, properties of materials, farad, henry, ohm, graph, switch, variables.

Mathematics: angles, constructing graphs and curves, Pythagorean theorem, phases angles, squares and square roots, solve algebraic equations, formulas, types of angles, types of triangles, length, magnitude, direction, ratio, time intervals, constants, percentage, direct proportion, types of curves.

M: series, frequency, rate, units of measurement, seconds, types of curves, powers of ten, scientific notation, characteristics of curves, greater than, less than, basic mathematical calculations.

Work ethic: selecting appropriate equipment, proper use of equipment, acquiring knowledge base for using techniques and procedures, following rules and procedures, learning fundamentals, proper uses of equipment, proper application of rules and conventions, following procedures, adhering to safety practices, attending to details, use of appropriate equipment, proper care and storage of equipment.

Communication: uses of symbols, interpreting symbols, interpreting graphs and curves, read and understand graphs, charts, and tables to obtain factual information.

Task B 1 - AC Circuits

B.1 TASK: Calculate and measure AC waveform time periods, frequencies, wavelengths, and voltages.

Science: circuits, AC circuits, waves, wave characteristics, waveforms, frequency, wavelength, voltage, current, direct current, signals, frames of reference, classification, pulse, period, sine wave, alternating current, sinusoidal wave, generator, oscillator, electrical power, basic characteristics, amperes, amplitude, peak value, volt/unit(s) of measurements, phase difference, speed of light.

S: variation, change, square wave, triangle wave, sawtooth wave, alternating current, polarity, volt, amp, rotation, hertz, phase.

Mathematics: simple calculations, time periods, time intervals, magnitude, value, basic trigonometry, characteristic curves, variation, square triangle, basic geometry, direction, angles, construction of graphs, cycles, axes, conversion of systems/units, powers of ten, length, rates, direct and inverse relationships.

M: period, frequency, constant, units of measurement, percent, direction, graph, positive, negative, zero, maximum, minimum, axis, horizontal, time, average, degree, conversion factor, formula, second, milli, increase, decrease, micro, mega, sine, cosine, tangent, angle.

Work ethic: selecting appropriate equipment, proper use of equipment, acquiring knowledge base for using techniques and procedures, following rules and procedures, learning fundamentals, proper uses of equipment, proper application of rules and conventions, following procedures, adhering to safety practices, attending to details, use of appropriate equipment, proper care and storage of equipment.

Communication: interpreting diagrams and figures, preparing curves and diagrams.

C: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, read and understand forms.

Task B 2 - AC Circuits

B.2 TASK: Use schematics to analyze, construct, and troubleshoot AC capacitive circuits.

Science: schematic diagrams, resistors, DC circuits, capacitor, AC circuit, capacitance, patterns, inductors, construction of electronic devices, component, properties of material, dielectric, farad, volts, classification, power supply, filter, rheostat, charge, AC circuit, DC voltage, change, characteristic behavior(s), reactance, frequency, series, parallel.

S: interaction, limitation, behavior of materials, use knowledge to construct devices, insulator, volt, ohm.

Mathematics: areas, distance, units of measurement, basic dimensions, powers of ten, rating, variation, formulas, frequency, inverse relationships.

M: percent, thickness, micro, pico, value, small, large, variable, function, pi, net, increase, decrease, degree, problem-solving, range, symbols.

Work ethic: uses of proper techniques and procedures, selecting appropriate equipment, proper use of equipment, acquiring knowledge base for using techniques and procedures, following rules and procedures, learning fundamentals, proper uses of equipment, proper application of rules and conventions, following procedures, adhering to safety practices, attending to details, use of appropriate equipment, proper care and storage of equipment.

C: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, or tables to obtain factual information, read and interpret diagrams, recognize and use symbols.

B.3 TASK: Using schematics to analyze, construct, and troubleshoot AC inductive circuits.

Science: circuits, properties of materials, behavior of materials, using knowledge to construct devices, distinguishing properties, properties of components, resistance, components of systems, current flow, electron flow, lines of force, magnetic fields, conductor, frames of reference, electromotive forces, forces, peaks, limiting factors, wave properties, properties of systems and system components, henry, phase, current, voltage, identify and manipulate variables, Ohm's Law, direct current, alternating current, phase shift, applied voltage, effective voltage, frequency, Lentz's Law, magnetic flux, series, parallel, basic components, vectors, power, gather and record data.

S: schematic diagram, inductor, inductance, change, peak, sine wave, relationships, patterns, mutual induction, resistor, inductor, phase angle, ohm.

Mathematics: proportion, rate, change, delta, basic trigonometry, sine, tangent, types of curves/waves, units of measurement, cycles, length, diameter, increase, decrease, formulas, equations, 3-dimensional space, coefficients, simple computations, standards, construction of graphs, derivation of equations, Pythagorean Theorem, squares and square roots, rearranging equations, powers of ten.

M: percent, axis, directly proportional, milli, micro, pi, angle, value, vectors, direction, magnitude, impedance, inversely proportional, range, superscript.

Work ethic: following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

Communication: interpret graphs, uses of symbols, interpreting diagrams, constructing clear diagrams.

C: read and understand graphs, charts, and tables to obtain information.

Task B 4

B.4 TASK: Using schematics, analyze and apply principles of transformers to AC circuits.

Science: circuits, alternating current, using knowledge to construct electrical devices, transformer, fields, forces, lines of force, energy transfer, classification, magnetism, induced magnetism, lines of flux, precision, properties of materials, types of transformers, voltage, current, phase, phase shift, uses of knowledge, hysteresis, magnetic field, properties of materials, resistance, power.

S: mutual inductance, primary, secondary, windings, variation, identify and manipulate variables, inductance, step-up transformer, output, input, step-down transformer, friction, inertia, heat, eddy current,

Mathematics: efficiency, ratio, formulas, direct proportion, inverse proportion, equations, solving for unknowns in equations, variation, rearranging equations.

M: increase, decrease, percent, equal, range, direction, squares and square roots, equivalent, decimal, domain.

Work ethic: following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

Communication: constructing proper diagrams, uses of symbols.

C: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain information, read and interpret diagrams.

Task B 5

B.5 TASK: Measure and calculate RC and RL circuit characteristics including integration and differentiation.

Science: characteristics of systems, circuits, resistance, capacitor, inductor, series, parallel, voltage, current, power source, AC source, in phase, out of phase, resistance, DC circuit, impedance, schematic diagrams, change, instantaneous voltage, input signal, phase angle.

S: behavior of materials, uses of knowledge, lead, lag, compare and contrast, control variables, types of waves.

Mathematics: measurement skills, simple calculations, use of equipment, integration, differentiation, time intervals, arithmetic addition, trigometric addition, uses of formulas, squares and square roots, angles, triangle, inverse relationship, ratio, basic trigonometry, tangent, solving equations, sum, increment, proportional, rate, magnitude, direction, constant, constants.

M: time, units of measurement, percent, value, problem solving.

Work ethic: uses of proper techniques and procedures, selecting appropriate equipment, proper use of equipment, acquiring knowledge base for using techniques and procedures, following rules and procedures, learning fundamentals, proper uses of equipment, proper application of rules and conventions, following procedures, adhering to safety practices, attending to details, use of appropriate equipment, proper care and storage of equipment.

Communication: uses of symbols.

C: read, understand, and gather information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain information.

Task B 6

B.6 TASK: Using schematics, analyze, construct and troubleshoot RLC circuits.

Science: systems and their components, circuits, resistors, inductors, capacitors, basic electrical devices, amplify, interference, noise, series circuits, units of measurement, ohm, Ohm's Law, power, power factor, resistance, phase analog, phase out-of-phase, vectors, voltage drop, impedance, ampere, parallel circuits, limiting factors, AC circuits, identifying variables.

S: problem-solving, ohm.

Mathematics: frequencies, uses of formulas, solving equations, greater than, less than, equalities, inequalities, squares and square roots, ratio, algebraic equations, simple computations, constructing graphs, basic trigonometry, tangent, arc tangent, parallel, complex numbers, reciprocal, problem-solving, using calculators, ordering, complex numbers, real numbers, imaginary numbers, basic angles, substitution, cosine, sine.

M: percent, net, vectors, branching, problem-solving, positive, negative, rectangle, multiples, zero, degree, algebraic addition.

Work ethic: following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

Communication: interpreting graphs and figures.

C: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, or tables to obtain information.

Task B 7

B.7 TASK: Using schematics analyze, construct, and troubleshoot series and parallel resonant circuits.

Science: series circuits, parallel circuits, resonant circuits, inductive reactance, resonance, AC circuit, tuning, rheostat, reactance, capacitor, inductor, circuits, frame of reference, phase, out of phase, resistance, ohms, properties of systems, inductance, Hertz, frequency, limiting factors, current flow, voltage, phase angle, current, impedance, resistor, characteristics of components, Ohm's Law.

S: problem-solving, turning, uses of knowledge, variation, leads, ohm, phase angle, response curve.

Mathematics: increase, decrease, direct relationships, indirect relationships, frequency, equivalence, angles, cancel, net effect, types of curves, square roots, inverse relationships, solving for unknowns in equations, maximum, minimum, summation, parallel, rate, ratio, formulas, range, width, simple calculations.

M: equal to, percent, zero, net, properties of curves, kilo, pi, units of measurement, combination, degree.

Work ethic: following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

Communication: use of symbols.

C: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, or tables to obtain information.

Task B 8

B.8 TASK: Using schematics analyze, construct and troubleshoot filter circuits.

Science: circuits, current, frequency, voltage, power source, band, filter, current flow, capacitor, resistor, limits, shunt, impedance, resonance circuit, parallel resonant circuit.

S: problem-solving, classification, limits, limiting factors, short, ground, short-circuit, inductor.

Mathematics: frequency, range, percentage, characteristic curves, types of curves.

M: set,subset, kilo, units of measurement, value.

Work ethic: following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

C: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, or tables to obtain information.

Task B 9

B.9 TASK: Analyze delta and wye three phase power circuits.

Science: circuits, voltage, volts, phase, alternator, armature, windings, output voltage, out of phase, phase relationship, waves, types of waves, wave characteristics, voltages, AC voltage, induction, series, current, generator, three phase, ground.

S: advantage, relationships, patterns, neutral.

Mathematics: delta, circle, basic trigonometry, sine, efficiency, simple calculations, basic dimensions, change, parallel, square roots.

M: conversion, percent, equal to, spatial relations.

Work ethic: using proper technique, developing basic skills, following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

C: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, or tables to obtain information.

Task C 1 - Solid State Devices

C.1 TASK: Identify the properties of semiconductor materials and explore semiconductor diodes.

Science: properties of materials, induced properties of materials, behavior of materials, semiconductors, diode, solid state, solid state devices, systems, using knowledge to construct devices, uses of materials, conductors, insulators, serial ordering, atoms, elements, atomic structure, electron configuration, characteristic properties, classification, ions, neutral, electronegativity, chemical bonding, ionic bonds, covalent bonds, molecules, thermal properties, thermal conductivity, current, resistance, electron excitation, valence, identifying variables, electron movement, attraction, repulsion, voltage, bias, types of voltages, thermal effects, Bohr model of the atom, particle nature of matter, circuits, components of circuits, criterion variables.

S: resistance, charge, junction, potential difference, barrier voltage, leakage, peak, change, record and use data, cathode, anode.

Mathematics: coefficient, inverse proportion, types of mathematical curves, constant, constants, development of codes, range, limits.

M: percent, time, dichotomy, direct proportion, standards, prefixes, tri, penta, decimals, rate, increase, decrease, greater than, equal to, less than, direction, width, straight line, triangle.

Work ethic: using proper technique, developing basic skills, following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

WE: store equipment properly.

Communication: interpreting diagrams and figures, use of symbols, constructing schematic diagrams.

C: read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information.

Task C 2

C.2 TASK: Examine zener diode characteristics and other diodes.

Science: dielectric, capacitor, capacitance, power, current, turner, rheostat, junction, oscillator, generator, frequency, peak, valley, rectifier, switch, resistor, variation, microwaves, alternator, DC current, energy.

S: uses of knowledge, use knowledge to construct devices,function, voltage, voltage source, schematic diagram, circuit, properties of materials, behavior of materials, temperature, heat, power, dissipate, shunt, load, tolerance, power supply, volt, amp, ohm, output, bias, insulator, charge, voltage, velocity, resistance, record and use data.

Mathematics: rate, ratings, value/units of measurement, frequency, ratio, construction of graphs and curves.

M: percent, time, reliable, constant, limits, minimum, maximum, basic arithmetic, fractions, part/whole relationships, linear, inverse relationship, basic geometry, increase, decrease, peak, valley, bi, direction, decimal, range, parallel, positive, negative.

Work ethic: using proper technique, developing basic skills, following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

WE: develop laboratory skills, store equipment properly.

Communication: interpreting diagrams and figures, use of symbols, constructing schematic diagrams.

C: read, understand, and find information or gather data from books, manuals, directories or other documents,
read and understand graphs, charts, and tables to obtain factual information.

Task C 3

C.3 TASK: Examine bipolar transistor characteristics.

Science: transistor, solid state, construction of electronic systems, components of systems, polar, bipolar, uses of knowledge, element, semiconductor, properties of materials, current, direction, bias, current flow, voltage, resistance, power, amplification, polarity, limiting factors, controls, junction, change, circuit, voltage drop, resistance, signal, terminal, energy, power source, output voltage, input voltage, electrical devices, ohmmeter, open circuit, short circuit, uses of devices, characteristics and attributes.

S: systems, oscilloscope, element, classification, amplifier, rectifier, load, resistor, frames of reference, signal, energy, power source, record and use data, inference, classification.

Mathematics: area, order, direction, classification, range, function, solving simple equations, simple computations, formula, change, constant, constants, direct proportion, variation, percentage, difference, equal, portion, value, units of measurement, time, time intervals.

M: thickness, direction, section, variation, rearrange variables, problem-solving, increase, decrease, percent, value, part/whole relationships.

Work ethic: following rules, using proper technique, developing basic skills, following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

WE: store equipment properly.

Communication: uses of symbols, interpretation of figures and diagrams.

C: read, understand, and find information or gather data from books, manuals, directories or other documents,
read and understand graphs, charts, and tables to obtain factual information.

Task C 4

C.4 TASK: From a schematic diagram, analyze, construct, and troubleshoot a common base amplifier.

Science: solid state, solid state device, amplifier, classification, properties of materials, circuit, systems, components of systems, transistor, amplification, current, voltage, power, impedance, phase relationships, input signal, resistor, characteristics of circuits, characteristics of systems, characteristics of curves, interpretation of data, DC current, limitation, frequency, period, Hertz, transistor, characteristic curves, variables, critical variables.

S: schematic diagram, amplifier, systems, input, output, oscilloscope, gain, frames of reference, change, waveforms, phase, volt, amp, hertz, element.

Mathematics: spatial relationships, increase, gain, greater than, smaller than, types of mathematical curves, direct relationships, indirect relationships, interpolate, extrapolate, construction of graphs and curves, family of curves, variation, frequency, period, percentage.

M: percent, time, units of measurement, coordinates, vectors, subscripts, value, decimals, milli, limits, ratio, equal to, range vary, powers of ten.

Work ethic: following rules, using proper technique, developing basic skills, following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

WE: store equipment properly.

Communication: development of languages, uses of symbols, construct diagrams, figures, and tables.

C: read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information.

C.5 TASK: From a schematic diagram, analyze, construct and troubleshoot a common emitter amplifier.

Science: classification, amplifier, systems, model building, circuits, schematic diagrams, transistor, characteristics of systems, properties of materials, current voltage, power, impedance, phase, polar, power source, patterns, change, current, frequency, limits, efficiency, frames of reference, reference points, current flow, leakage.

S: problem-solving, decision-making, input, output, record and use data, oscilloscope, gain, signal, bipolar, amplification, volt, amp.

Mathematics: construction of graphs and curves, properties of curves, families of curves, direct relationships, inverse relationships, interpolate, extrapolate, units of measurement, simple calculations, variable, variation, use of formulas, problem-solving, solving for unknowns in equations, frequency, time intervals, period, percentage.

M: spatial relationships, dichotomy, percent, time, set, subset, coordinates, vary, measurement, vectors, value, basic calculations, subscript, milli, micro, decimals, integer, limits, time, zero.

Work ethic: proper use of instruments, following rules, using proper technique, developing basic skills, following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

WE: store equipment properly.

Communication: uses of symbols, interpret graphs, tables and figures.

C: read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information.

Task C 6

C.6 TASK: From a schematic diagram analyze, construct, and troubleshoot a simple common collector amplifier.

Science: bipolar, transistor, amplifier, signal, characteristic properties, classification, uses of components, unique uses, impedance, range, circuits, properties of circuits, resistor, voltage, bias, current, power, AC, DC, resistance, approximation, estimation, circuit boards/diagrams, limiting factors, diodes, limitation, power, temperature, current flow, temperature effects.

S: schematic diagram, problem-solving, decision-making, input, output, uses of knowledge, multimeter, oscilloscope, gain, record and use data, waveforms, safety, watt, interaction, heat sink, dissipation.

Mathematics: range, ratio, summation, solving for unknowns, rearrangement of equations, maximum, minimum, limits, rate, rating, rank, watt, powers of ten.

M: percent, Greek alphabet, formulas, value, subscript, units of measurement, prefixes, milli.

Work ethic: following procedures, proper use of instruments, following rules, using proper technique, developing basic skills, following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

WE: store equipment properly.

Communication: construct proper figures and diagrams, interpret figures and diagrams.

C: read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information.

Task C 7

C.7 TASK: Examine the characteristics of FEC transistor.

Science: transistor, amplifier, characteristics of components, classification, solid state, electrical devices, uses of knowledge to construct devices, impedance, resistance, units, ohm, voltage, signal, elements, bipolar, bias, current, physical characteristics, amplification, chemical reactions, oxidation, oxides, semiconductor, insulator, conduction, conductivity, limitations, threshold, static electricity, lead(s).

S: generator, ohmmeter, multimeter, oscilloscope, input, volt, element, substrate, load, output, forms of communication, transconductance, mho, gain, metal, oxide, polarity, electron, field, charge, change, phase.

Mathematics: fractions, decimals, direct relationships, inverse relationships, patterns, characteristic curves, measurement, ratio, simple calculations, 3-dimensional space.

M: percent, time, units of measurement, prefixes, mega, subscript, positive, negative, reverse, majority, increase, decrease, point, units of measurement, primary, region, vectors, mode, majority, zero, thin, degree.

Work ethic: following procedures, proper use of instruments, following rules, using proper technique, developing basic skills, following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

WE: store equipment properly.

Communication: construct proper figures and diagrams, interpret figures and diagrams.

C: read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information.

Task C 8

C.8 TASK: From a schematic diagram analyze, construct, and troubleshoot a simple common source amplifier.

Science: amplifier, bipolar, transistor, circuits, schematic diagrams, characteristics of systems, uses of equipment, current, voltage, value, lead(s), bias, resistor, voltage divider, series circuit, parallel circuit, AC voltage, amplitude, resistance, load, input signal, classification.

S: problem-solving, decision-making, power supply, ohmmeter, multimeter, oscilloscope, generator, input, output, gain, uses of knowledge, AC current, DC current, change.

Mathematics: variable, variation, range, value.

M: spatial relations, percent, time, units of measurement, digital, relative position, subscript, region, minimum, maximum, mode, increase, decrease, zero, limits, dichotomy.

Work ethic: following procedures, proper use of instruments, following rules, using proper technique, developing basic skills, following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

WE: store equipment properly.

Communication: construct proper figures and diagrams, interpret figures and diagrams.

C: read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information.

Task C 9

C.9 TASK: From a schematic diagram analyze, construct, and troubleshoot a simple common drain amplifier.

Science: amplifier, bipolar, transistor, circuit, characteristics of devices, signal, output, source, voltage, resistance.

S: schematic diagram, problem-solving, decision-making, classification, power supply, input, short circuit, ground, record and use data.

Mathematics: percent, time, units of measurement, mode, greater than, equal to, less than, range.

Work ethic: following procedures, proper use of instruments, following rules, using proper technique, developing basic skills, following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

WE: follow instructions or directions in the performance of a specific task, use correct equipment, use equipment properly, follow safety precautions, store equipment properly.

Communication: construct proper figures and diagrams, interpret figures and diagrams.

C: read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information.

Task C 10

C.10 TASK: From a schematic diagram, analyze, construct, and troubleshoot a simple common gate amplifier.

Science: amplifier, bipolar, transistor, circuits, distinguishing characteristics, conduction, conductivity, organization, input signal, schematic diagram, bias voltage, voltage, resistance, stable, solid state, use knowledge to construct devices.

S: problem-solving, decision-making, classification, control, electrical circuits, input, output, polarity, gain, components, stable, record and use data.

Mathematics: frequency.

M: percent, time, units of measurement, subscript, variation, mode, range.

Work ethic: following procedures, proper use of instruments, following rules, using proper technique, developing basic skills, following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

WE: store equipment properly.

Communication: construct proper figures and diagrams, interpret figures and diagrams.

C: read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information.

Task C 11

C.11 TASK: From a schematic diagram, analyze, construct, and troubleshoot thyrister operations.

Science: solid state, component, switch, conductor/conducting, classification, AC power, DC power, bipolar, transistors, types of switches, semiconductor, junction, properties of materials, resistance, units of measurement, voltage, bias, diode, semiconductor rectifier, leads, conductor, cathode, current flow, microwaves.

S: schematic diagram, problem-solving, decision-making, use knowledge to construct devices, ohm, circuit(s), characteristics of materials, oscillator, forms of communication, conduct, positive, cathode, anode, simple machines, microwaves, record and use data generator, pulse.

Mathematics: equivalent, simple arithmetic, ratio, simple formulas, standards, direct relationships, simple computations, unidirectional.

M: logic, deductive logic, percent, spatial relations, units of measurement, range, kilo, subscript, greek letters/alphabet, decimals, direction, mode, limits, bidirectional, negative, uniform, integers.

Work ethic: proper use of equipment, following procedures, proper use of instruments, following rules, using proper technique, developing basic skills, following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

WE: store equipment properly.

Communication: construct proper figures and diagrams, interpret figures and diagrams.

C: read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information.

Task C 12

C.12 TASK: From a schematic diagram analyze, construct and troubleshoot an integrated circuit operational amplifier.

Science: amplifier, circuit, integrated circuit, efficiency, current, voltage, power, limiting factors, classification, ampere, units of measurement, schematic diagrams, signal, AC, DC, component, analog, constriction of equipment, resistance, feedback, Hertz, oscillate, phase, distortion, uses of knowledge.

S: problem-solving, decision-making, relativity, dissipation, input, output, forms of communication, components, open circuit, gain, approximate, phase, out of phase, volt, closed circuit.

Mathematics: proportional, linear, range, ratio, solving equations, frequency, simple calculations.

M: cost, limits, digital, time, percent, mega, spatial relations, analog, resistance, subscript, positive, negative, degree, formulas.

Work ethic: proper use of equipment, following procedures, proper use of instruments, following rules, using proper technique, developing basic skills, following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

WE: store equipment properly.

Communication: equipment for communication, uses of symbols, construct proper figures and diagrams, interpret figures and diagrams.

C: read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information.

Task C 13

C.13 TASK: A schematic diagram analyze, construct, and troubleshoot optoelectronic devices.

Science: solid state, solid state devices, classification, circuit, photosensitive, light sensitive, energy transfers, generating current, photoelectric cell, resistor, change, resistance, photovoltaic cell, energy conversion, energy, electrical energy, solar cell, sources of electricity, semiconductor, uses of equipment, light meter, schematic diagrams, resistor, generator, atomic structure, diode, photodiode, electromagnetic radiation, ultraviolet, infrared, spectrum, incandescent, intensity, uses of knowledge.

S: problem-solving, decision-making, use knowledge to construct devices, component, units of measurement, career education, photo cell, forms of communication.

Mathematics: inverse proportion, non-linear, curvilinear, area, surface area, direct relationship, limits, frequency.

M: percent, time, units of measurement, set, subset, increase, decrease.

Work ethic: proper use of equipment, following procedures, proper use of instruments, following rules, using proper technique, developing basic skills, following directions, checking against standards, checking for accuracy/precision, attending to details, using appropriate procedures, proper use and care of equipment, following safety procedures.

WE: store equipment properly.

Communication: equipment for communication, uses of symbols, construct proper figures and diagrams, interpret figures and diagrams.

C: read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information.

Task D 1 - Analog Circuits

D.1 TASK: Using a schematic analyze, construct and troubleshoot single-stage transistor amplifiers.

Science: schematic diagram, identify variables, analyze systems, components of systems, transistor, amplifier, analog, circuits, analog circuits, bias, Ohm's Law, resistance, feedback, bias resistor, ohm, volt, distortion, fidelity, voltage drop, impedance, limits, establishing rules and conventions, voltage divider, power source, shunt, input signal, model building, characteristic properties, junction, radio waves, static, receiver, phase shift, ground, battery, impedance matching, gain, bipolar, identify variables, gather and record data, power supply, sources of electricity, interpret data, temperature gradients, expansion and contraction, transformer, function, drawing conclusions.

S: problem-solving, uses of knowledge, single-stage, network, stable, limiting factors, heat, classification, diode, change, ambient temperature, frequency, approximation, short circuit, interaction, hybrid, relationships.

Mathematics: angles, triangles, interpolate, units of measurement, ratio, solving simple equations, standards, direct relationships, fractions, part-whole relationships, simple calculations, constant, trade-offs, value, efficiency, decimals, powers of ten, positive, negative, characteristic curves, constructing graphs and curves, inverse relationships, equal, unequal, less than, greater than, subscript, differences, range, family of curves, linear, summation, frequency, maximum, minimum, parameters, basic measurements.

M: half, constant, point, coordinates, exact, temperature, ratio, spatial arrangements, unity, micro, set, subset, criterial attributes, zero, increase, decrease, percent, parallel.

Work ethic: following rules and conventions, proper use of equipment, attend to details, use of proper equipment, following safety procedures, proper storage of equipment.

Communication: use of symbols, construction of diagrams and figures, interpret diagrams.

C: read,understand and find information or gather data from books, manuals, directories or other documents,
read and understand graphs, charts, and figures to obtain information.

Task D 2

D.2 TASK: Using a schematic analyze, construct and troubleshoot multi-stage transistor amplifiers.

Science: schematic diagram, transistor, amplifier, analog circuits, characteristic properties, solid state, impedance, voltage gain, power gain, ground, input, output, resistors, bias, phase shift, voltage drop, capacitor, series, parallel, short circuit, shunt, gain, input signal, bypass, load, forces, variables, identifying variables, power source, Ohm's Law, potentiometer, resistance, matching impedance, open circuit, frequency, capacitance, transformer, gather and record data, series, parallel, coupling, stage, flow charting, classification, problem-solving, distortion, feedback, stability, oscillator, gain.

S: emitter amplifier, swamping resistor, change, reliable, limitation, variation, accuracy.

Mathematics: direct and indirect relationships, change, fractions, ratio, internal, external, maximum, minimum, squares, simple calculations, solving equations, range, band, limits, equal, constant, linear dimensions, construct graphs, inversely proportional, properties, decision-making.

M: degree, increase, decrease, zero, decimal, part-whole relationships, square, square root, formula, frequency, limits, thickness, coordinates, deductive logic, subscript, units of measurement, multiples, value, standard, error, percent, point.

Work ethic: proper selection of equipment, following steps and procedures, following rules and conventions, proper use of equipment, attend to details, use of proper equipment, following safety procedures, proper storage of equipment.

Communication: use of symbols, interpret diagrams.

C: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and figures to obtain information.

Task D 3

D.3 TASK: Using a schematic analyze, construct and troubleshoot power supplies.

Science: schematic diagrams, power supply, power source, limitations, control variables, circuits, components of circuits, identify variables, direct current, sources of electricity, alternating current, energy conversion, rectifier, components of systems, diode, waveform, polarity, pulsating, bridge, half-wave rectifier, transformer, ripple, load, cycle, positive, negative, open circuit, volts, variables/factors, limits, tolerances, surge, ohm, filter, peak, inductor, vacuum tube, integrated circuit, voltage regulator, shunt, series, parallel, wattage, power, heat sink, ground, components, temperature, units of measurement, ohmmeter, voltmeter, oscilloscope.

S: problem-solving, control variables, full-wave rectifier, electron, peak, change, waveform, capacitance, limitation, charge, precision, classification, shunt, series, dissipate, change, excess, silicon, heat sink.

Mathematics: basic trigonometry, efficiency, percentage, fractions, multiples, inverse relationships, constant, superimpose, percent, average, equal, value, variation, characteristic curves, equations, solving equations, change, greater than, less than, decimals, standards, powers of ten, sum, logical thinking, steps in problem-solving, units of measurement.

M: time, time intervals, equal to, degree, number, increase, decrease, maximum, minimum, angle, equal to limit, milli, microprocessor, parallel, variation, chip, cost, deductive logic, criterial attributes.

Work ethic: following directions, following rules and conventions, proper use of equipment, attend to details, use of proper equipment, following safety procedures, proper storage of equipment.

Communication: uses of symbols, interpret diagrams.

C: read, understand and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and figures to obtain information.

Task D 4 - Analog Circuits

D.4 TASK: Using a schematic analyze, construct and troubleshoot differential operational amplifiers.

Science: Schematic diagrams, instrumentation, circuit, integrated circuit, voltage, power, gain, amplifier, systems, processes of science, construction of devices, use of knowledge, analysis of data, input, output, terminals, waveforms, signal, components, relativity, noise, uses of knowledge, ground, phase, out of phase, in phase, model building, ideal, impedance, design, decibel, voltage, resistance, volt, Hertz, change, blackbox, feedback, Ohm's Law, Kirchhoff's Law, ohm, resistor, parameters, components of systems.

S: problem-solving, terminal, ideal, change.

Mathematics: linear, larger than, smaller than, integration, differentiation, simple calculations, digital, symmetry, mode, equal, infinity, linear dimensions, ratio, use of formulas, magnitude, units of measurement, basic logarithms, value, increase, decrease, frequency, powers of ten, decimal, fraction, range, rate, time intervals, fixed, limits, minimum, maximum, orders of magnitude, construction of graphs, slope, interpret graphs, interpolate, product, balance.

M: percent, operation, part-whole relationships, degree, unity, width, spatial relationships, point, positive, negative, proportion.

Work ethic: Proper use of equipment, learn basic vocabulary, following directions, following rules and conventions, attend to details, use of proper equipment, following safety procedures, proper storage of equipment.

Communication: Development of vocabulary, interpret diagrams, use symbols, interpret symbols, design, basic vocabulary.

C: read, understand and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and figures to obtain information.

Task D 5

D.5 TASK: Explore industrial applications for operational amplifiers.

Science: uses of knowledge, construction of devices, construction of equipment, characteristics of equipment, circuits, basic science, applied science, concept(s) of technology, amplify, input signal, circuit, voltage, volt, wave, characteristic properties, ground, square wave, out-of-phase, signal, hysteresis, voltage divider, series, parallel, noise, static, schematic diagram, generator, capacitor, feedback, resistor, waveform, identifying and manipulation variables, uses of science and technology in industry.

S: operational amplifier, comparator, sine wave.

Mathematics: Increase, difference, standard, frames of reference, reference point, units of measurement, basic trigonometry, sine, ratio, sum, simple calculations, solving equations, constant, frequency, inverse relationship, product, area, function, integral, assumptions, problem-solving, plus or minus.

M: percent, solving for unknowns, rate, zero, spatial relations, subscript, positive, negative, degree, opposite.

Work ethic: Proper use of equipment, learn basic vocabulary, following directions, following rules and conventions, attend to details, use of proper equipment, following safety procedures, proper storage of equipment.

Communication: development of vocabulary, interpret figures and diagrams.

C: read, understand and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and figures to obtain information.

Task D 6

D.6 TASK: Using a schematic analyze, construct and troubleshoot active filters.

Science: schematic diagram, filter, uses of knowledge in electronics and industry, analysis of data, amplitude, volt, second, waves, square wave, circuit, resistor, capacitor, active, passive, design, change, voltage, capacitance, resistance, series, parallel, load, prediction.

S: problem-solving, operational amplifier, basic electricity, current, systems, critical frequency, conditions, environment, ohm, equation.

Mathematics: inverse relationship, product, units of measurement, integral, range, limits, frequency, uses of equations, square root, solving equations, problem-solving, product, simple calculations, order, value, multiples, combinations, substitution of equivalence, squares, direct relationships.

M: percent, width, spatial relations, series, equal to multiple, ratio, fraction, superscript, subscript, ground, critical value, center, double.

Work ethic: Proper use of equipment, learn basic vocabulary, learn basic procedures, following directions, following rules and conventions, attend to details, use of proper equipment, following safety procedures, proper storage of equipment.

Communication: uses of vocabulary, interpreting figures and diagrams.

C: read, understand and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and figures to obtain information.

Task D 7

D.7 TASK: Using a schematic analyze, construct and troubleshoot solid state oscillators.

Science: schematic diagrams, solid state, oscillator, use knowledge to construct devices, circuits, waveforms, analysis of data, analysis of systems, transistor, feedback, in phase, design, phase-shift, amplifier, output, network, characteristic behaviors, bridge, flow charts, construction of models, resonance, signal, amplitude, inductor, quality control, generator, capacitance, limits, crystal, characteristic properties, atomic structure, characteristic waves, classification, types of wave, approximation, bias, DC current, filter, components, diagnosis and problem-solving.

S: oscillator, inductor, stable, relaxation oscillator, sawtooth wave, approximation, junction, evaluation, charge, discharge, attenuation, vibration.

Mathematics: basic geometry, families of curves, basic trigonometry, symmetry, variation, frequency, additive, square root, inverse relationships, range, powers of ten, dichotony, product, optimum, multiples, greater than, unity, approximate, similar, congruent, proportion.

M: basic attributes, shape, spatial relations, degree, network, ratio, units of measurement, value, limits, solving for unknowns, increase, decrease, positive, negative, percent.

Work ethic: Proper use of equipment, learn basic vocabulary, learn basic procedures, following directions, following rules and conventions, attend to details, use of proper equipment, following safety procedures, proper storage of equipment.

Communication: interpret diagrams and figures, interpret figures, interpret symbols, use of symbols.

C: read, understand and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and figure to obtain information.

Task D 8 - Pulse Circuits

D.8 TASK: Using a schematic analyze, construct and troubleshoot basic pulse circuits.

Science: schematic diagram, pulse, circuits, classification, career education, digital, microprocessor, waveform, voltage, change, types of curves, oscilloscope, waves, square waves, network, components, characteristic properties, ground, discharge, resistance, capacitance, accuracy, precision.

S: problem-solving, basic electricity, patterns, charge, threshold, external, junction, tolerance.

Mathematics: digital, microprocessor, units of measurement, time intervals, magnitude, linear measurements, cycle, repetitive, geometric figures, periodic, symmetrical, frequency, reciprocal, inverse relationships, construction of graphs and curves, slope, delta, change, constants, deriving equations, metric units, equations, solving equations, value, percentage.

M: percent, measurement, width, repetition, positive, negative, vertical, flat, periodic, rate, random, fractions, ratio, standards, frame of reference, sequence, increase, decrease, complement, range, kilo, minimum, maximum, nano, seconds, solving for unknowns, standard value.

Work ethic: Proper use of equipment, learn basic vocabulary, learn basic procedures, following directions, following rules and conventions, attend to details, use of proper equipment, following safety procedures, proper storage of equipment.

Communication: constructing diagrams, graphic communication, interpret figures and diagrams, interpret graphs, use of symbols.

C: read, understand and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and figures to obtain information.

Task D 9 - Modulation Circuits

D.9 TASK: Using a schematic analyze, construct and troubleshoot modulation circuits.

Science: schematic diagram, circuits, analyze data, uses of knowledge, energy, electrical energy, energy conversion, energy transfer, classification, frequency, frequency modulation, amplitude modulation, signal, circuit, signal generator, gather and record data, diode, waveforms, vacuum tube, series, DC supply, voltage, capacitor, inductor, saturation, transformer, power, oscillator, amplifier, capacitance, bipolar, transistor, vacuum tube, phase, sine wave.

S: problem solving, communication, magnetism, amplitude, accuracy.

Mathematics: amplitude, frequency, constant, cycle, function, percentage, proportion, minimum, maximum, progressive, efficiency, variations, advantage, disadvantage, basic trigonometry.

M: percent, linear, nonlinear, progression, binary numbers, greater than, less than, sample, rate.

Work ethic: proper procedures for gathering data, proper use of equipment, learn basic vocabulary, learn basic procedures, following directions, following rules and conventions, attend to details, use of proper equipment, following safety procedures, proper storage of equipment.

Communication: interpret figures and diagrams.

C: read, understand and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and figures to obtain information.

Task E 1 - Digital Electronics

E.1 TASK: Define digital and analog circuits, and differentiate between digital logic families.

Science: circuits, digital circuits, analog circuits, diversity, characteristic properties, classification, integrated circuits, linear, signal, voltage, ground, level, uses of knowledge to construct devices, waveforms, generator, variation, flow charts, pulse, output, resistor, discrete, resistance, criterion variable, transistor, power supply, limitations, diode, speed, units of measurement, schematic diagrams, ampere, current, bipolar, power, series, parallel, element, metal, oxide, semiconductor, power supplies, noise, insulator, electrostatic, static electricity, shunt, parameter.

S: taxonomy, operational definition, sine wave.

Mathematics: sets, subsets, dichotomy, direction, continuous, basic trigonometry, construct and interpret graphs, sine waves, relationship of variables, range, minimum, maximum, logic and logical rules, frequency, mode, rate, powers of ten, standards, fractions, decimals, advantage, disadvantage, greater than, less than.

M: digital, analog, linear, group, variation, point,period, interval, family, polar, milli, approximate, value, absolute value.

Work ethic: work without the need for close supervision, follow directions or instructions in the performance of a specific task.

Communication: interpret diagrams and figures, uses of symbols, development of vocabulary.

C: read, understand, and gather information or find data in books, manuals, directories, or other documents,
read and understand graphs, charts, and tables to obtain factual information.

Task E 2

E.2 TASK: Use binary, decimal, and hexadecimal numbering systems.

Science: system(s), circuit, switch, digital circuits, use knowledge to construct devices.

Mathematics: number systems, binary, decimal, hexidecimal, equivalence, conversion, number bases, octal, digit, superscript, subscript, place value, position, basic arithmetic, powers of ten, significant figures, relative position, norms, fractions, decimals, exponential, central/central tendency, direction, infinity, most significant digit, least significant digit, weighting system, equal to, basic logic.

M: microprocessor, percent, positive, negative, multiple, center, exponent, position, amount, power.

Work ethic: learn basic language.

Communication: uses of symbols, development of communication systems, interpret data tables, development of vocabulary, common terminology.

C: read, understand, and gather information or find data in books, manuals, directories, or other documents,
read and understand graphs, charts, and tables to obtain factual information.

Task E 3

E.3 TASK: Verify basic Boolean expressions using truth tables and logic gates.

Science: flowcharts, dichotomies, inferences, logical deduction, systems, basic attributes, characteristics, classification, circuit, integrated circuit, closed system, black box, construction of models, schematic diagram, current, voltage, ampere, volt, power supply, circuit board, gather and record data, interpret data, prediction, use knowledge to construct devices, ground, symptoms, plausible, pulse, construct and interpret graphs, validity/credibility, amp, volt, switch, open circuit, closed circuit, ground, critical attributes, chip, patterns, series, parallel, standards, frames of reference.

S: naming, experiment, identify and control variables, problem-solving, pattern.

Mathematics: Boolean, truth tables, logic, binary systems, families, range, parameter, minimum, maximum, units of measurement, powers of ten, fractions, decimal, limits, construct and interpret graphs, variation, deviation, sequence/sequential, interpolate, inverse relationship, conversion, equivalence, increase, decrease, time interval, critical point, combinations, powers of ten, orders of magnitude, mathematic systems.

M: deductive logic, percent, positive, negative, cost, dichotomous, odd, even.

Work ethic: memorize basic symbols, learn basic information, familiarize with basic tools and equipment, use basic tools and equipment, follow rules and conventions (selection of appropriate tools and equipment, recording information properly/keep proper records, following directions, determining proper operation, attending to details, use equipment properly, follow safety rules, proper care of equipment).

Communication: uses of symbols, interpretation of symbols, interpretation of diagrams and charts, construct tables and charts.

C: read, understand, and gather information or find data in books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information.

E.4 TASK: Using NAND logic, construct basic logic circuits from Boolean expressions.

Science: use knowledge to construct devices/circuits, circuits, systems, model-building, designing systems and models, gathering and analyzing data, parsimony, organizing data, verification/credibility, integrated circuits, schematic diagram, use knowledge to develop systems, identify and control variables, limitations, variable.

S: career education, constructing maps, input, output,

Mathematics: Boolean algebra, logic, combinations, simple computations, basic arithmetic, dichotomy, binary, efficiency, equivalence, summation, product, Communicative Law, Associative Law, Distributive Law, construct graphs and data recording systems.

M: deductive logic, combinations, percent, DeMorgan's laws, NAND logic, rules, algorithms, cost, spatial relationships, function, systems, mathematical models, Karnaugh maps, sum, product, sum of products, minimum, maximum, simplification, complement, vertical, horizontal, cancel.

Work ethic: selection of proper equipment, record data properly, learn basic knowledge behind practical/practitioner work, learn more than required, learn basic rules, practice basic skills (selection of appropriate tools and equipment, recording information properly/keep proper records, following directions, determining proper operation, attending to details, use equipment properly, follow safety rules, proper care of equipment).

Communication: uses of symbols, forms of communication, interpreting figures and diagrams, interpreting data, use of references, construction of maps.

C: read, understand, and gather information or find data in books, manuals, directories, or other documents,
read and understand graphs, charts, and tables to obtain factual information.

E.5 TASK: Use logic diagrams to analyze, construct, and troubleshoot encoding and decoding circuits.

Science: schematic diagrams, logic diagrams, logic, gather and analyze data, interpret data, signal, circuits, digital circuits, generator, parity, classification, criterial attributes, use knowledge to construct devices, anode, cathode, current, data reduction, energy transfer, input, output, control variables, bit, approximation.

S: problem-solving, systems, resistor, ohm, optical illusion, perception/observation.

Mathematics: functions, conversion, binary, compare and contrast, logic, dichotomy, equivalence, discrete, increase, decrease, efficiency, range, capacity, direction, number systems, sequence, ordering, scale diagrams, units of measurement, discrete, continuous, magnitude, equal, greater than, less than, attribute, quantity, odd, even, basic computations, error, sources of error.

M: percent, decimal, standards, spatial arrangements, segment, microprocessor, sequence, time, rate, digit.

Work ethic: selection of appropriate tools and equipment, recording information properly/keep proper records, following directions, determining proper operation, attending to details, use equipment properly, follow safety rules, proper care of equipment.

Communication: develop communication systems, develop symbols and codes, interpreting codes and figures, writing to communicate.

C: read, understand, and gather information or find data in books, manuals, directories, or other documents,
read and understand graphs, charts, and tables to obtain factual information.

E.6 TASK: Use logic diagrams to analyze, construct, and troubleshoot flip-flops.

Science: schematic diagrams, logic diagrams, gather and analyze data, use knowledge to construct systems and devices, circuits, bit, pulse, feedback.

S: problem-solving, input, output, record data, characteristic properties, characteristic behavior, patterns, classification.

Mathematics: logic, sequence, sequential logic, combination, time, time intervals, combinational logic, equal, spatial relationships, frequency.

M: deductive logic, memory, sequence, percent, positive, negative, complement.

Work ethic: selection of appropriate tools and equipment, recording information properly/keep proper records, following directions, determining proper operation, attending to details, use equipment properly, follow safety rules, proper care of equipment.

Communication: develop communication systems, develop symbols and codes, interpreting codes and figures, writing to communicate.

C: read, understand, and gather information or find data in books, manual, directories, or other documents,
read and understand graphs, charts, and tables to obtain factual information.

E.7 TASK: Analyze, construct and troubleshoot basic multivibrator circuits.

Science: schematic diagrams, gather and analyze data, interpret data, inference, circuit, model-building, waveforms, sequential circuits, use knowledge to construct devices, generator, timers, systems, digital systems, charge, capacitor, waves, voltage, pulse, sine wave, amplifier, components of systems, integrated circuits, transistor, digital, bipolar, feedback, resistor, resistance, ohm, Hertz, approximation.

S: problem-solving, patterns, periodic, vibration, square wave, estimation.

Mathematics: oscillate, frequency, analogy, time intervals, rate, period, constants, cycle, percentage, proportion, basic trigonometry, sine, sinusoidal, characteristic attributes, discrete, square wave, families of curves, inverse relationship, product, decimals, value, inversely proportional, time constant, units of measurement, variation, range, critical point, limits, simple calculations, construction and interpretation of graphs, interpolation, fractions, powers of ten, duration/length, intersection, vertical, horizontal, diagonal, approximate, exact, ratio, basic calculations.

M: percent, symmetrical, pico, micro, second, interpolate, rules.

Work ethic: selection of appropriate tools and equipment, recording information properly/keep proper records, following directions, determining proper operation, attending to details, use equipment properly, follow safety rules, proper care of equipment.

Communication: develop communication systems, develop symbols and codes, interpreting codes and figures, writing to communicate, uses of references.

C: read, understand, and gather information or find data in books, manuals, directories, or other documents,
read and understand graphs, charts, and tables to obtain factual information.

Task E 8

E.8 TASK: Analyze, construct, and troubleshoot basic counter circuits.

Science: schematic diagrams, gather and analyze data, interpret data, circuits, digital circuits, analog circuits, classification, characteristic properties, counter, systems, integrated circuits, concept formation, inductive logic, pulse, series, change, interaction, timing, timer, switch, speed, critical variables, use knowledge to construct systems and devices, Hertz, resistance, waveforms, noise, power, power supply, voltage.

S: problem-solving, speed, use knowledge to construct devices, operational definition, power dissipation.

Mathematics: simple calculations, number, time intervals, increase and decrease, cumulative, range, binary, combinations, frequency, units of measurement, sine wave.

M: count/counting, number, rate, percent, mode, decade, order, cycle, significant digit.

Work ethic: selection of appropriate tools and equipment, recording information properly/keep proper records, following directions, determining proper operation, attending to details, use equipment properly, follow safety rules, proper care of equipment.

Communication: developing basic language/vocabulary.

C: read, understand, and gather information or find data in books, manuals, directories, or other documents,
read and understand graphs, charts, and tables to obtain factual information.

Task E 9

E.9 TASK: Analyze, construct, and troubleshoot basic shift register circuit.

Science: schematic diagrams, gather and analyze data, circuits, digital circuits, systems, components of systems, characteristic properties, patterns, bits, classification, limitations, serial, parallel, pulse, transfer, input, output, speed of light, strobe, uses of knowledge.

S: problem-solving.

Mathematics: serial ordering, parallel, time intervals, range, upper and lower limits, mode.

M: memory, percent, byte, low, high, direction.

Work ethic: learn basic vocabulary, selection of appropriate tools and equipment, recording information properly/keep proper records, following directions, determining proper operation, attending to details, use equipment properly, follow safety rules, proper care of equipment.

Communication: develop basic vocabulary.

C: read, understand, and gather information or find data in books, manuals, directories, or other documents,
read and understand graphs, charts, and tables to obtain factual information.

E.10 TASK: Analyze, construct, and troubleshoot basic arithmetic circuits.

Science: schematic diagrams, gather and record data, analyze and interpret data, circuits, use knowledge to construct devices, systems, integrated circuits, microprocessor, input, output, limitations, bit, significant, speed, orders of magnitude, parallel, rotation.

S: problem-solving, adder, chip.

Mathematics: simple arithmetic, simple calculations, binary, value, range, units of measurement, powers of ten, scientific notation, rearranging equations and numbers, logic, logic unit, computer, microprocessor, algorithm, problem-solving, product, part-whole relationships, accumulate, rotation, operation.

M: number systems, percent, binary arithmetic, complement, program.

Work ethic: learn basic knowledge and techniques, learn basic vocabulary, selection of appropriate tools and equipment, recording information properly/keep proper records, following directions, determining proper operation, attending to details, use equipment properly, follow safety rules, proper care of equipment.

Communication: interpret diagrams and figures, uses of symbols, development of vocabulary.

C: read, understand, and gather information or fine data in books, manuals, directories, or other documents,
read and understand graphs, charts, and tables to obtain factual information.

Task E 11

E.11 TASK: Analyze, construct, and troubleshoot basic digital logic systems and circuits.

Science: schematic diagrams, gather and record data, analyze and interpret data, systems, logic, logical deduction, digital circuits, circuits, logic circuits, use knowledge to develop systems, use knowledge to construct instruments and devices, basic science, variables, criterial attributes, identify and control variables, problem-solving, sequence, patterns, inference, organization, multimeter, power, current resistance, ohm, amp, volt, units of measurement, continuity, power supply, short, ground, intensity, oscilloscope, signal, amplitude, compare and contrast, cathode ray tube, electron configuration, characteristic properties, observation, interaction, manipulating variables, flowcharts, using flowcharts.

S: technology, technological devices, organization, decision-making, pictorial models, magnetic field, observation, inference.

Mathematics: function, range, maximum, minimum, limits, construct and interpret graphs, time, frequency, logic, sequence, order.

M: percent, memory.

Work ethic: follow rules and procedures, practice techniques and skills, study continuously, organize and maintain your work area, assemble and organize resources/references, learn more than is required, proper use of equipment, patience and persistence, think positively, acquire basic knowledge behind skills and techniques, identify/recognize necessary equipment, take time to prepare, recognize basic equipment, acquire much and many experiences, (selection of appropriate tools and equipment, recording information properly/keep proper records, following directions, determining proper operation, attending to details, use equipment properly, follow safety rules, proper care of equipment), following directions.

Communication: develop communication systems, develop symbols and codes, interpreting codes and figures, writing to communicate, uses of references.

C: read, understand, and gather information or find data in books, manuals, directories, or other documents,
read and understand graphs, charts, and tables to obtain factual information.

Task E 12

E.12 TASK: Analyze the operation of a typical microprocessor system.

Science: flowcharts, use of flowcharts, integrated circuit, pulse, transfer, circuit, classification, bit, schematic diagram.

S: problem-solving, schematic diagrams, integrated circuit, classification, magnetism, magnetic effects, dynamic, speed, system, volatile, variation, use of knowledge to construct devices, buffer, semiconductor, power, density, technology, signal, compare and contrast, capacitor, charge.

Mathematics: central processing unit, spatial relationships, area, sequence, mathematical operations, rate, cycle, time intervals, logical operations, arithmetic operations, fractions, function.

M: memory, percent, digital, static, random, rate, cost, nano, second, units of measurement, fit, chip, program, efficiency, polar, positive, negative.

Work ethic: memorize basic symbols, learn basic information, familiarizewith basic tools and equipment, use basic tools and equipment, follow rules and conventions (selection of appropriate tools and equipment, recording information properly/keep proper records, following directions, determining proper operation, attending to details, use equipment properly, follow safety rules, proper care of equipment).

Communication: develop basic vocabulary.

C: read, understand, and gather information or find data in books, manuals, directories, or other documents,
read and understand graphs, charts, and tables to obtain factual information.

Task E 13

E.13 TASK: Analyze, construct, and troubleshoot digital-to-analog and analog-to-digital computers.

Science: problem-solving, part-whole relationships, use of knowledge to construct devices, voltage, AC, signal, change, circuit, speed, resolution, temperature, stability, network, series, resistor, parallel, resistance, junction, shunt, ground, integrated circuit, pulse, feedback, accuracy, measurement, classification, successive approximation, balance, decision-making, counter, variation, hysteresis, error.

Mathematics: digital, analog, memory, percent, weight, binary, sum, value, equal to direction, time, period, time interval, sequence, efficiency, set, fractions, slope, inverse relationship, ratio, range, linear.

Work ethic: memorize basic symbols, learn basic information, familiarize with basic tools and equipment, use basic tools and equipment, follow rules and conventions (selection of appropriate tools and equipment, recording information properly/keep proper records, following directions, determining proper operation, attending to details, use equipment properly, follow safety rules, proper care of equipment).

Communication: interpret diagrams and figures, uses of symbols, development of vocabulary.

C: read, understand, and gather information or find data in books, manuals, directories, or other documents,
read and understand graphs, charts, and tables to obtain factual information.

Task E 14

E.14 TASK: Analyze the operation of a typical microprocessor system.

Science: flowcharts, use of flowcharts, integrated circuit, pulse, transfer, circuit, classification, bit, schematic diagram.

S: system, microprocessor, problem-solving.

Mathematics: central processing unit, spatial relationships, area, sequence, mathematical operations, rate, cycle, time intervals, logical operations, arithmetic operations, fractions, function.

M: percent, program.

Communication: develop basic vocabulary.

C: read, understand, and gather information or find data in books, manuals, directories, or other documents,
read and understand graphs, charts, and tables to obtain factual information.

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Task F1.1 - Operate Microprocessor

F1.1 TASK: Describe the operation of microcomputer and microprocessor systems.

Science: macro, micro, use knowledge to build devices, basic electricity, circuits and their characteristics, classification, characteristic properties, systems, digital systems, integrated circuits, concept of technology, magnetism and magnetic properties, sources of error, bits, organization, direction, vectors.

S: chip, component, input, output, cathode ray tube, language, patterns.

Mathematics: binary, operations, problem-solving, basic arithmetic, efficiency, probability, error, octal, hexadecimal, conversion, equivalence, number systems, spatial relationships.

M: digital, set, subset, deductive logic, random, microprocessor, fractions, part/whole relationships, arithmetic logic, mode, range, size, infinity, branching, rate, percent.

Work ethic: learn knowledge used to construct devices.

WE: follow instructions or directions in the performance of a specific task, use proper equipment, use equipment properly follow safety precautio, store equipment properly.

Communication: learn basic vocabulary, development of codes, forms of communication.

C: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information,and understand the meaning of words in sentences.

Task F1.2 - Bus Structure

F.1 2 TASK: Diagram and define the bus structure of a microprocessor.

Science: systems, communicating, basic electricity, magnetism, classification, systems, subsystems, circuits, use knowledge to construct devices, schematic diagrams, characteristic properties, concept of technology, circuit boards, properties of materials, signals, voltage, data transformation, orders of magnitude, current.

S: components, multiplex, pulse, load, chip, standard.

Mathematics: set, subset, digital, equivalence, function, level, number systems, standards, direction, prefixes (uni, bi).

M: percent, pair, microprocessor, logic, deductive logic, K, memory, time, synchronous, value, unidirectional, dichotomous, norm, area, size, cost, efficient.

Work ethic: learn to use references.

WE: follow instructions or directions in the performance of a specific task, use proper equipment, use equipment properly follow safety precautions, store equipment properly.

Communication: learn basic vocabulary.

C: use diagrams and figures to communicate
read, understand, and find information or gather data from books, manuals, directories, or other documents,
read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

Task F.1 3 - Run Machine Language

F.1 3 TASK: Enter, verify, and run a machine language program.

Science: concept of technology, uses of knowledge to construct devices, pulse.

Mathematics: discrete, number systems, hexidecimal, speed, increment.

M: percent, microprocessor, memory, time, rate, list, complement, calculate, successive, logic, sequence, memory.

Work ethic: follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

WE: practice, develop and maintain basic skills.

Communication: learn basic vocabulary.

C: use diagrams and figures to communicate
read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, understand the meaning of words in sentences.

Task F1.4 - Architecture of Microprocessor

F.1 4 TASK: Diagram and define the architecture of a microprocessor.

Science: construct models, blackbox, inference, systems, components of systems, using knowledge to design and construct devices, bits, speed, pulse, classification, signal, power, sound.

S: ground.

Mathematics: draw to scale, function, timing, time intervals, cycle, logical operations, arithmetic operations, range, rate, serial, set and subset, product.

M: percent, counter, direction, counter, K, sequence, deductive, logic, discrete, cost.

WE: follow instructions or directions in the performance of a specific task, use proper equipment, follow safety precautions, store equipment properly.

Communication: develop coding systems.

C: use diagrams and figures to communicate
read, understand graphs, charts, and tables to obtain factual information read, understand, and find information or gather data from books, manuals, directories, or other documents, and understand the meaning of words in sentences.

Task F.1 5 - Machine Language Arithmetic

F.1 5 TASK: Write, enter, verify, and run machine language arithmetic programs.

Science: classification, designing systems, flowcharts, analyze and interpret data, creative thinking.

S: change.

Mathematics: number systems, conversion, order, sequence, set, subset, sign, parity, arithmetic operations, problem-solving, logical operations, error.

M: percent, two's complement, pair, length, sequence, size, memory, consecutive.

Work ethic: learn basic rules, learn basic knowledge, learn to use manuals and references, regularly maintain equipment, check your work, develop patience and persistence, follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

WE: practice.

Communication: use of printed sources.

C: compose logical and understandable written correspondence or directives, use diagrams and figures to communicate, read, understand and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

Task F.1 6 - Machine Language Branching

F.1 6 TASK: Write, enter, verify and run machine language branching programs.

Science: systems, components of systems, flowcharts, branching, data transfer, creative thinking, designing systems using knowledge.

S: dependence, limitation, conditions, identify and control variables.

Mathematics: linear, cycle, loop, equivalence, logical deduction, sequence.

M: percent, branching, decision-making, odd, even, parity, direction, operation, problem-solving.

Work ethic: regular and proper use of manuals, follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

Communication: interpret charts, tables and codes.

C: Compose logical and understandable written correspondence or directives, use diagrams and figures to communicate, read, understand and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, understand the meaning of words in sentences.

Task F.1 7 - Operation of the Stack

F.1 7 TASK: Write, enter, verify, and run machine programs demonstrating the operation of the stack.

Science: systems and subsystems, use knowledge to design and construct devices.

S: classification, variable.

Mathematics: logic, logical deductions, length, set and subset, hexadecimal.

M: percent, successive, size, order, high, low, greater than, less than.

Work ethic: practice, follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

Communication: interpret charts and tables.

C: compose logical and understandable written correspondence or directives, use diagrams and figures to communication, read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

Task F.1 8 - Programming using Algorithms

F.1 8 TASK: Write, enter, verify, and run machine language programs demonstrating the operation of simple algorithms.

Science: flowcharts, deductive logic, classification.

S: processes of science, change.

Mathematics: algorithm, problem-solving, set, subset, simple calculations, binary, basic geometric shapes, standards, branching.

M: percent, logic, finite, basic arithmetic, error, decision-making, variables, branching, length, variation, point, order, sequence.

Work ethic: learn and follow rules, follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

Communication: use of symbols, interpret tables and charts.

C: use diagrams and figures to communicate, compose logical and understandable written correspondence or directives, read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

Task F.1 9 - Input/Output & Interrupts

F.1 9 TASK: Write, enter, verify and run machine language programs demonstrating the operation of input/output and interrupts.

Science: system, subsystem, input, output, deductive logic, problem solving, designing systems, flowcharts, classification, pulse.

S: interaction.

Mathematics: function, dichotomous, standards, branching, direction, vector, serial, accumulate.

M: percent, scale, chip, vector, part/whole relationships.

Work ethic: proper use of manuals, follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

Communication: use of charts and figures.

C: use diagrams and figures to communicate, compose logical and understandable written correspondence or directives, read, understand graphs, charts, and tables to obtain factual information, read and understand graphs, charts, and tables to obtain factual information understand the meaning of words in sentences.

Task F.1 10 - Interrupt Operations

F.1 10 TASK: Prepare the software and hardware to perform the interface operations with RAM and display.

Science: interface, interaction, classification, characteristic properties, magnetic properties, magnitude, system, bit, schematic diagram, circuits, density, circuit board, voltage, ultraviolet light, power, flowchart.

S: volatile, system, expansion, static, dynamic, pulse, model-building, parsimony.

Mathematics: spatial relations, area, magnitude, parity, powers of ten, scientific notation, plus or minus, range, low, high, digit, conversion, deductive logic.

M: random, percent, time area, K, units of measurement, milli, series, sequence, digit, segment, problem-solving, percent.

Work ethic: learn basic vocabulary and rules, use of references, follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

Communication: preparation of maps, interpret tables and charts.

C: read, understand and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

Task F.1 11 - Interface Operations 6800

F.1 11 TASK: Prepare the software and hardware to reform interface operations with switches and LED's.

Science: characteristic properties, classification, interfacing, input, manipulate data, magnetism, systems, subroutines, output, model building, change.

S: mass production, physical change, change.

Mathematics: loop, cycle, function, alpha, numeric, alphanumeric, operation.

M: percent, cost, range, discrete, analog, digital, logic.

Work ethic: proper use of manuals, follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

Communication: interpret figures and charts.

C: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

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Task F.1 12 - Interface Digital to Analog

F.1 12 TASK: Prepare the software and hardware to interface digital to analog converters to the microprocessor.

Science: interfacing, signal, voltage, volts, current, circuits, data manipulation, pulse, continuous, potentiometer, resistor, rheostat, resistance, fluid, variable, frames of reference, reference points, switch, amplifier, temperature, coefficient.

S: resolution.

Mathematics: digital, analog, data conversion, logic, units of measurement, binary, significant, fraction, sum, linear, exponential, polar, positive, negative, coefficients, accuracy, relative.

M: percent, variable, value, prefixes (uni, bi), absolute, relative, time.

Work ethic: follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

Communication: interpret charts and figures.

C: read. understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

Task F.1 13 - Interface Analog to Digital

F.1 13 TASK: Prepare the software and hardware to interface analog to digital converters to the microprocessor.

Science: interface, change, data manipulation, use knowledge to construct devices, resolution, characteristic properties, conversion, parallel, amplitude, voltage, speed, generator, fixed, circuits, precision, signal.

S: dependence, classification, problem-solving, successive approximation, pulse, parameters.

Mathematics: digital, analog, conversion, binary, large numbers, rate, slope, cycle, accuracy, cost, greater than, less than, advantage, disadvantage, parameters.

M: percent, quantity, ratio, part/whole relationships, error.

Work ethic: use of manuals, keeping up-to-date, follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

Communication: interpret charts and figures.

C: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

Task F2.1 - Operate Microprocessor (6800)

F2.1 TASK: Describe the basic operation of a microprocessor and a microcomputer.

Science: macro, micro, use knowledge to build devices, basic electricity, circuits and their characteristics, classification, characteristic properties, systems, digital systems, integrated circuits, concept of technology, magnetism and magnetic properties, sources of error, bits, organization, direction, vectors.

S: chip, component, input, output, cathode ray tube, language, patterns.

Mathematics: binary, operations, problem-solving, basic arithmetic, efficiency, probability, error, octal, hexadecimal, conversion, equivalence, number systems, spatial relationships.

M: digital, set, subset, deductive logic, random, microprocessor, fractions, part/whole relationships, arithmetic logic, mode, range, size, infinity, branching, rate, percent.

Work ethic: learn knowledge used to construct devices.

WE: follow instructions or directions in the performance of a specific task, use proper equipment, use equipment properly, follow safety precautions, store equipment properly.

Communications: learn basic vocabulary, development of codes, forms of communication.

C: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences .

F.2 2 - Numbering Systems and Codes

F.2 2 TASK: Convert numbers from one radix to another and explain the function of binary codes.

Science: systems, processes of science, variables, classification, conditions, limitation, volt, input, output, relative position, frames of reference, uses of knowledge, compare and contrast, standards, interfacing, speed change, difference, instantaneous, parity.

Mathematics: Percent, number systems, decimal, binary, hexadecimal, conversion, alphanumeric, codes, operation, number bases, count, function, dichotomy, logic, deductive logic, position, point, value, powers of ten, exponents, multiples, superscript, scientific notation, sequence, radix (base), basic arithmetic, subscript, octal, efficiency, equivalent, uses of knowledge, range, mode, integer, discrete, rate, increase, fractions, units of measurement, second, decimals, equal to.

Work ethic: follow instructions or directions in the performance of a specific task acquire fundamental knowledge.

Communication: forms of communication.

C: acquire basic vocabulary, read, understand, and gather data or find information from books, manuals, directories, or other documents, compose logical and written correspondence, write logical and understandable statements.

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Task F.2 3 - Machine Language Program

F.2 3 TASK: Enter, verify, and run a machine language program.

Science: concept of technology, uses of knowledge to construct devices, pulse.

Mathematics: discrete, number systems, hexidecimal, speed, increment.

M: percent, microprocessor, memory, time, rate, list, complement, calculate, successive, logic, sequence, memory.

Work ethic: follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

WE: practice, develop and maintain basic skills.

Communication: learn basic vocabulary.

C: use diagrams and figures to communicate, read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

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Task F.2 4 - Machine Language Arithmatic

F.2 4 TASK: Write, enter, verify, and run machine language arithmetic programs.

Science: classification, designing systems, flowcharts, analyze and interpret data, creative thinking.

S: change.

Mathematics: number systems, conversion, order, sequence, set, subset, sign, parity, arithmetic operations, problem-solving, logical operations, error.

M: percent, two's complement, pair, length, sequence, size, memory, consecutive.

Work ethic: learn basic rules, learn basic knowledge, learn to use manuals and references, regularly maintain equipment, check your work, develop patience and persistence, follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

WE: practice.

Communication: use of printed sources.

C: compose logical and understandable written correspondence or directives, use diagrams and figures to communicate, read, understand and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

Task F.2 5 - Machine Language Branching

F.2 5 TASK: Write, enter, verify and run machine language branching programs.

Science: systems, components of systems, flowcharts, branching, data transfer, creative thinking, designing systems using knowledge.

S: dependence, limitation, conditions, identify and control variables.

Mathematics: linear, cycle, loop, equivalence, logical deduction, sequence.

M: percent, branching, decision-making, odd, even, parity, direction, operation, problem-solving.

Work ethic: regular and proper use of manuals, follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

Communication: interpret charts, tables and codes.

C: Compose logical and understandable written correspondence or directives, use diagrams and figures to communicate, read, understand and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

Task F.2 6 - Programming using Algorithms

F.2 6 TASK: Write, enter, verify, and run machine language programs demonstrating the operation of simple algorithms.

Science: flowcharts, deductive logic, classification.

S: processes of science, change.

Mathematics: algorithm, problem-solving, set, subset, simple calculations, binary, basic geometric shapes, standards, branching.

M: percent, logic, finite, basic arithmetic, error, decision-making, variables, branching, length, variation, point, order, sequence.

Work ethic: learn and follow rules, follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

Communication: use of symbols, interpret tables and charts.

C: use diagrams and figures to communicate, compose logical and understandable written correspondence or directives, read, understand, and find information or gather data from books, manuals, directories, or other documents read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

Task F.2 7 - Architecture of the 6800

F.2 7 **TASK:** Diagram and define the architecture of a microprocessor.

Science: construct models, blackbox, inference, systems, components of systems, using knowledge to design and construct devices, bits, speed, pulse, classification, signal, power, sound.

S: ground.

Mathematics: draw to scale, function, timing, time intervals, cycle, logical operations, arithmetic operations, range, rate, serial, set and subset, product.

M: percent, counter, direction, counter, K, sequence, deductive, logic, discrete, cost.

WE follow instructions or directions in the performance of a specific task, use proper equipment, follow safety precautions store equipment properly.

Communication: develop coding systems.

C: use diagrams and figures to communicate, read, understand graphs, charts, and tables to obtain factual information, read, understand, and find information or gather data from books, manuals, directories, or other documents, and understand the meaning of words in sentences.

F.2 8 - Additional 6800 Address Modes

F.2 8 TASK: Write, enter, verify and run a machine language program using additional 6800 addressing modes.

Science: system, power.

Mathematics: percent, number systems, number base, bit, byte, high, low, range, operand, multiples, memory, increment, increase, decrease, index, point, spatial relations, operation, format, order, sequence, number.

Work ethic: follow instructions or directions in the performance of a specific task, use proper/required equipment follow safety precautions, and store equipment properly.

Communication: acquire basic vocabulary.

C: read, understand, and gather data or find information from books, manuals, directories, or other documents, compose logical and written correspondence, write logical and understandable statements.

Task F.2 9 - Operation of Stack in 6800

F.2 9 TASK: Write, enter, verify, and run machine programs demonstrating the operation of the stack.

Science: systems and subsystems, use knowledge to design and construct devices.

S: classification, variable.

Mathematics: logic, logical deductions, length, set and subset, hexadecimal.

M: percent, successive, size, order, high, low, greater than, less than.

Work ethic: practice, follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

Communication: interpret charts and tables.

C: compose logical and understandable written correspondence or directives, use diagrams and figures to communicate, read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

Task F.2 10 - Input/Output Using 6800

F.2 10 TASK: Write, enter, verify and run machine language programs demonstrating the operation of input/output and interrupts.

Science: system, subsystem, input, output, deductive logic, problem solving, designing systems, flowcharts, classification, pulse.

S: interaction.

Mathematics: function, dichotomous, standards, branching, direction, vector, serial, accumulate.

M: percent, scale, chip, vector, part/whole relationships.

Work ethic: proper use of manuals, follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

Communication: use of charts and figures.

C: use diagrams and figures to communicate, compose logical andunderstandablewritten correspondence or directives, read, understand graphs, charts, and tables to obtain factual information, read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

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Task F.2 11 - Bus Structure of 6800

F.2 11 TASK: Prepare the software and hardware to interface digital to analog converters to the microprocessor.

Science: interfacing, signal, voltage, volts, current, circuits, data manipulation, pulse, continuous, potentiometer, resistor, rheostat, resistance, fluid, variable, frames of reference, reference points, switch, amplifier, temperature, coefficient.

S: resolution.

Mathematics: digital, analog, data conversion, logic, units of measurement, binary, significant, fraction, sum, linear, exponential, polar, positive, negative, coefficients, accuracy, relative.

M: percent, variable, value, prefixes (uni, bi), absolute, relative, time.

Work ethic: follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

Communication: interpret charts and figures.

C: read. understand, and find information or gather data from books, manuals, directories, or other documents read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

Task F.2 12 - Interface with RAM and Displays

F.2 12 TASK: Prepare the software and hardware to perform the interface operations with RAM and display.

Science: interface, interaction, classification, characteristic properties, magnetic properties, magnitude, system, bit, schematic diagram, circuits, density, circuit board, voltage, ultraviolet light, power, flowchart.

S: volatile, system, expansion, static, dynamic, pulse, model-building, parsimony.

Mathematics: spatial relations, area, magnitude, parity, powers of ten, scientific notation, plus or minus, range, low, high, digit, conversion, deductive logic.

M: random, percent, time area, K, units of measurement, milli, series, sequence, digit, segment, problem-solving, percent.

Work ethic: learn basic vocabulary and rules, use of references, follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

Communication: preparation of maps, interpret tables and charts.

C: read, understand and find information or gather data from books, manuals, directories, or other documents read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

F.2 13 TASK: Prepare the software and hardware to reform interface operations with switches and LED's.

Science: characteristic properties, classification, interfacing, input, manipulate data, magnetism, systems, subroutines, output, model building, change.

S: mass production, physical change, change.

Mathematics: loop, cycle, function, alpha, numeric, alphanumeric, operation.

M: percent, cost, range, discrete, analog, digital, logic.

Work ethic: proper use of manuals, follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

Communication: interpret figures and charts.

C: read, understand, and find information or gather data from books, manuals, directories, or other documents read and understand graphs, charts, and tables to obtain factual information, and understand the meaning of words in sentences.

F.2 14 - Operate PIA in Both IN/OUT Modes

F.2 14 TASK: Prepare software and hardware to operate the PIA in both input and output modes.

Science: input, output, interface, interaction, chip, microprocessor, integrated circuit, buffer, limitations, design, decision-making.

Mathematics: percent, memory, location spatial relations, part/whole relationships, set, subset, sequence, number systems, number bases, function, accuracy, high, low.

Work ethic: follow instructions or directions in the performance of a specific task, use proper/required equipment follow safety precautions, and store equipment properly.

Communication: acquire basic vocabulary.

C: read, understand, and gather data or find information from books, manuals, directories, or other documents compose logical and written correspondence, write logical and understandable statements.

Task F.2 15 - Interface Analog to Digital and Digital to Analog (6800)

F.2 15 TASK: Prepare the software and hardware to interface analog to digital converters to the microprocessor.

Science: interface, change, data manipulation, use knowledge to construct devices, resolution, characteristic properties, conversion, parallel, amplitude, voltage, speed, generator, fixed, circuits, precision, signal.

S: dependence, classification, problem-solving, successive approximation, pulse, parameters.

Mathematics: digital, analog, conversion, binary, large numbers, rate, slope, cycle, accuracy, cost, greater than, less than, advantage, disadvantage, parameters.

M: percent, quantity, ratio, part/whole relationships, error.

Work ethic: use of manuals, keeping up-to-date, follow directions, use proper materials and equipment, use equipment properly, follow safety procedures, check to see that equipment operates properly, use proper guidebooks and references, proper care of equipment.

Communication: interpret charts and figures.

C: read, understand, and find information or gather data from books, manuals, directories, or other documents
read and understand graphs, charts, and tables to obtain factual information and understand the meaning of words in sentences.

Task G 1

G.1 TASK: Diagnose malfunctions applying logical troubleshooting techniques.

Science: logic, deductive logic, problem-solving, decision-making, identify and control variables, systems, subsystems uses of knowledge, career education, observation, use(s) of the senses, experiment, analysis, creative thinking, compare and contrast, evaluation, design and construction of equipment, components, limitation, classification, inference, input, output, record and use data, patterns, circuit, regularity, resistor, symptom, vibration, voltage, current, overload, friction, noise, watt, heat, thermal effects, function, accuracy, calibrate, uses of equipment, measurement, units of measurement, relative position, capacitor, properties of materials, behavior of materials, interaction, interdependence, variable, irregularity, transformer, resistance, signal, amplify, voltmeter, dynamic.

Mathematics: logic, sequence, percent, part/whole relationships, time efficiency, spatial relationships, basic probability, cycle, mode, norms, standards, location, variation, point, coordinates, frequency.

Work ethic: develop patience and persistence follow instructions or directions in the performance of a specific task, learn to use common sense, acquire basic knowledge and keep current, set priorities or the order in which several tasks will be accomplished, enumerate the possible causes of a problem, use efficient methods for eliminating the causes of a problem, identify important information needed to solve a problem, generate or conceive of possible alternate solutions to a problem, select activities to accomplish a specific task keep equipment and work area clean, locate information and select the materials, tools, equipment, or other resources to perform the activities needed to accomplish a specific task.

Communication: read, understand and gather data or find information in books, manuals, directories or other documents, forms of communication, read, understand graphs, charts, and tables to obtain factual information.

Task G 2

G.2 TASK: Prepare and Use Service records or documentations

Science: observation, record and use data, organization, classification, model(s), characteristics of materials, inference, systems, subsystems, change, prediction, criterial attributes, variation/diversity.

Mathematics: time, seriation, number, quantity, cost, estimation, percent, basic arithmetic, orders of magnitude, period.

Work ethic: follow instructions or directions in completion of a specific task.

Communication: read and understand form, compose logical and understandable written correspondence, short notes, or reports, write logical and understandable statements, phrases, or sentences to accurately fill out forms.

Task G 3

G.3 TASK: Read and convert measurements.

Science: variation, diversity, power, voltage, current, resistance, conductance, capacitance, inductance, variable, quantity, amount, scientific notation, ampere, systems, measurement, volts, record and use data.

Mathematics: measurement, units of measurement, standard, value, percent, criteria, time, greater than, equal to, smaller than, milli, kilo, micro, mega, conversion, decimals, whole number,equivalent, conversion.

Work ethic: follow instructions or directions in the completion of a specific task, acquire basic, fundamental knowledge, use proper equipment, use equipment properly, follow safety precautions, and store equipment properly.

Communication: read and understand graphs, charts, and tables to obtain factual information.

G.4 TASK: Set Up and Operate Counters and Generators

Science: electrical circuits, signal, input, systems, generator, counter, uses of knowledge, use knowledge to construct devices, meters, waveforms, oscillator, compare and contrast, standard, frames of reference, problem-solving, amplification, hertz, limitation, impedance, voltage, diversity, variation, classification, radio frequency, audio frequency, sine wave, square wave, peak, power, triangle waveform, sawtooth waveform, inverted pulse waveform, modulation, change, career education, vernier.

Mathematics: time, frequency, oscillation, percent, measurement, units of measurement, period, function, decade, digit, number, large numbers, mega, time intervals, range, low, high, curves, families of curves, digital, logic, approximation, micro, width, second, cycle.

Work ethic: learn to operate basic equipment, use proper equipment, use equipment properly, and store equipment properly.

Communication: read, understand, and find information or gather data in books, manuals, directories, or other document, read and understand graphs, charts, and tables to obtain factual information, forms of communication.

G.5 TASK: Set Up and Operate Oscilloscopes.

Science: circuits, uses of knowledge to construct devices, oscilloscope experiment, inference, voltage, frames of reference, waveforms, cathode ray tube, relationships, patterns, volts, amplitude, deflection, change, sweep, intensity, control variables, function, best fit, calibration, magnification, factor, order of magnitude, variation, voltmeter,ground, accuracy, parallax, impedance, sine wave.

Mathematics: measurement, units of measurement, percent, rate, time, construct and interpret graphs, spatial relations, coordinates, axes, vertical, horizontal, dimension, period, part/whole relationships, magnitude, scale, metric system of measurement, relative position, decimals, prefixes, approximation, increase,degree, cycle, vary, micro, second, slope, rotation.

Work ethic: learn construction/operation of basic equipment learn to operate basic equipment, use proper equipment, use equipment properly, and store equipment properly.

Communication: read, understand and find information or gather data in books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, and forms of communication.

Task G 6

G.6 TASK: Set up and operate multi-meter and power supplies

Science: electrical circuits, uses of knowledge, uses of knowledge to construct devices, power, power supply, multimeter, meter (instrument), instrumentation, voltage, volts, line voltage, standards, identify and control variables, change, regulate, control, load, vacuum tube, source, limitation, resistance, polar, bi-polar, amplifier, precision, ohm, amp, classification, resistance, shunt, impedance, ammeter, parallel, series.

Mathematics: percent, time, units of measurement, frequency, norms, multiple, variable, range, decimals, low, high, value, part/whole relationships, analog, digital, digit, function, quantity, rotate, clockwise, spatial relations, position, scale, positive, negative, kilo, quantity.

Work ethic: learn construction/operation of basic equipment learn to operate basic equipment, use proper equipment, use equipment properly, and store equipment properly.

Communication: read, understand, and find information or gather data in books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information, and forms of communication.

Task G 7

G.7 TASK: Operate an impedance bridge.

Science: uses of knowledge to construct devices, impedance, impedance bridge, inductance, capacitance, resistance, conductance, bridge, circuit, bridge circuit, components, properties of materials, systems, problem-solving, resistor, capacitor, inductor, compare, and contrast, accurate, schematic diagram, amplifier, DC voltage, AC voltage, series, parallel, record and use data, classification.

Mathematics: percent, measurement, units of measurement, criterial attributes, dichotomy.

Work ethic: learn construction/operation of basic equipment learn to operate basic equipment, use proper equipment, use equipment properly, and store equipment properly.

Communication: acquire basic vocabulary, learn basic concepts, read, understand, and find information or gather data in books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, forms of communication.

Task G 8

G.8 TASK: Set up and operate capacitor inductor analyzers

Science: capacitor, inductor, capacitance, inductance, circuit, use of knowledge to construct devices/equipment, calibration limitation, record and use data.

Mathematics: measurement, units of measurement, percent.

Work ethic: care for equipment properly, learn to operate basic equipment, learn construction/operation of basic equipment, use proper equipment, use equipment properly, and store equipment properly.

Communication: read, understand, and find information or gather data in books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, and forms of communication.

Task G 9

G.9 TASK: Set up and operate semiconductor testers and curve tracers.

Science: semiconductor, accuracy, transistor, use knowledge to construct equipment, circuit, classification, diode, polarity, cathode, anode, element, properties of materials, attributes, patterns, record and use data, tolerance, light sensitive, change, oscilloscope, voltage, current, capacitance, temperature, design, signal, generator, variable, amplitude, wave characteristics, sweep voltage, pulsating, polarity, transistor, precision, resistor, dynamic, specifications, schematic diagrams, saturation, limitation, linearity, distortion.

Mathematics: curve, percent, dichotomy, subscript, gain, measurement, time, construct and interpret graphs, units of measurement, minutes, rate, value, family of curves, linear, sorting, spatial relations, constant, continuous, positive, negative, range, increment, invert, vertical, horizontal, proportional, zero, minimum, maximum, increase, decrease, parameters, linear.

Work ethic: work effectively when time, tension, or pressure, are critical factors for successful performance, care for equipment properly, learn construction/operation of basic equipment, learn to operate basic equipment, use proper equipment, use equipment properly, and store equipment properly.

Communication: read, understand, and find information or gather data in books, manuals, directories, or other documents, read and understand graphs, charts, and tables to obtain factual information, and forms of communication.

Task G 10

G.10 TASK: Identify types of connectors and their uses.

Science: audio frequency, radio frequency, classification, conductor, DC, power, circuit.

Mathematic: percent, set, subset.

Task H 1

H.1 TASK: Record data design curves and graphs.

Science: gather and record data, analyze and interpret data, organize data, organization, construct and interpret graphs, patterns, classification, variables, relationships, units of measurement, uses of knowledge and skills, observation, drawing conclusions, history of science and technology, serendipity, discrepant events, summarize data.

S: prediction, inference, amplifier, controls, compare and contrast, frames of reference, parameters, model building, coltage, volts.

Mathematics: types of curves, axis, vertical, horizontal, position, families of curves, types of graphs, line of best fit, types of data, income, percentage, profit, fractions, decimals, pie charts, characteristic curves, constant, value, set, subset, parameters, basic probability.

M: line graph, circle graph, bar graph, time, units of measurement, increase, decrease, quantity, period, subscript, interpolate, extrapolate, angles, right angle.

Work ethic: utilize proper procedures, attend to detail, practice basic skills check for accuracy, follow basic procedures, learn and practice using basic forms and reports.

Communication: interpret graphs and charts, forms of communication, representation of ideas/displaying ideas, targetted communications, construction of models, prepare written reports, organization of ideas, use proper grammar and spell correctly, rules for good communication, learn vocabulary common to the field, use of appendices, etc., use of examples, learn basic writing skills.

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Task H 2

H.2 TASK: Write reports.

Science: communication, career education, function, uses of knowledge, interactions of science and society, organization, operational definition, change, temperature, transistor, parameters, limitation, technology, schematic diagram, error, serendipity.

Mathematics: percent, sequence, seriation.

Work ethic: follow instructions or directions in the performance of a specific task.

Communication: read, understand and find information or gather data from books, manuals, periodicals or other documents, read and understand forms, read and understand short notes, memos, and letters, read and understand graphs, charts, and figures to obtain factual information, understand the meanings of words in sentences, compose logical and understandable written correspondence/reports, forms of communication, targetted audiences.

Task H 3

H.3 TASK: Make equipment failure reports.

Science: organization, record and use data, inference, classification, limitation, temperature, conditions, variables, schematic diagram, testing/experimentation, models, observation.

Mathematics: time, time interval.

Work ethic: follow instructions or directions in the performance of a specific task.

Communication: read, understand and find information or gather data from books, manuals, periodicals or other documents, read and understand forms, read and understand short notes, memos, and letters, read and understand graphs, charts, and figures to obtain factual information, understand the meanings of words in sentences, compose logical and understandable written correspondence/reports, forms of communication, targeted audiences.

Task H 4

H.4 TASK: Specify and requisition specific electronic components.

Science: attribute, properties of materials, sample, population.

Mathematics: percent, quantity, cost, unit price, basic arithmetic, order.

Work ethic: follow instructions or directions in the performance of a specific task.

Communication: read, understand and find information or gather data from books, manuals, periodicals or other documents, read and understand forms, read and understand short notes, memos, and letters, read and understand graphs, charts, and figures to obtain factual information, understand the meanings of words in sentences, compose logical and understandable written correspondence/reports, forms of communication, and targeted audiences.

Task H 5

H.5 TASK: Compose technical letters.

Science: organization, classification.

Mathematics: spatial relations.

Work ethic: follow instructions or directions in the performance of a specific task.

Communication: read, understand and find information or gather data from books, manuals, periodicals or other documents, read and understand forms, read and understand short notes, memos, and letters, read and understand graphs, charts, and figures to obtain factual information, understand the meanings of words in sentences, compose logical and understandable written correspondence/reports, forms of communication, targeted audiences.

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Task H 6

H.6 TASK: Write formal reports of laboratory experiments.

Science: laboratory, experiment, identify and control variables, processes of science, record and use data, schematic diagram, patterns.

Mathematics: cycle, accurate, percent.

Work ethic: follow instructions or directions in the performance of a specific task.

Communication: read, understand and find information or gather data from books, manuals, periodicals or other documents, read and understand forms, read and understand short notes, memos, and letters, read and understand graphs, charts, and figures to obtain factual information, understand the meanings of words in sentences, compose logical and understandable written correspondence/reports, forms of communication, targeted audiences.

Task I 1 - Technical References

I.1 TASK: Use numerical IC reference manuals to identify manufacturers of various electronic devices.

Science: uses of knowledge to construct devices, communication, systems, integrated circuits, variation, record and use data, classification, problem-solving, identify and control variables, criterial attributes, chip, observation, function, taxonomy, frames of reference, interface.

Mathematics: efficiency, alphanumeric, uses of computers, number, percent, part/whole relationships, sequence, digital.

Work ethic: keep up-to-date, learn to use printed resources, make clear records, use of equipment properly, attending to details, care for equipment properly.

WE: follow instructions or directions in the performance of a specific task, set priorities or the order in which several tasks will be accomplished.

Communication: uses of symbols, interpreting codes.

C: read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information, compose logical and understandable written correspondence.

Task I 2

I.2 TASK: Use manufacturers' reference manuals to identify specific characteristics of various electric devices.

Science: criterial attributes, variation, record and use data, system, subsystem, classification, problem-solving, use of keying systems, multi-stage classification systems, organization.

S: identify and control variables, properties of materials, operational definitions, voltage, input, output.

Mathematics: set, subset, percent, large numbers, component, reliability, rate/rating, minimum, maximum, range.

Work ethic: learn to use basic equipment, be accurate and be neat, proper care of equipment.

WE: follow instructions or directions in the performance of a specific task, set priorities or the order in which several tasks will be accomplished.

Communication: uses of symbols, interpreting codes, uses of definitions, interpret figures and charts.

C: read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information, compose logical and understandable written correspondence.

Task I 3

I.3 TASK: Use reference manuals to identify manufacturers and distributors of various electronic devices.

Science: identify variables, record and use data, systems, subsystems, organization, use of keying systems, uses of knowledge to construct devices, criterial attributes, problem-solving.

S: solid state, motor, integrated circuits, observation, inference, taxonomy, amplifier, crystal, power supply.

Mathematics: percent, spatial, relations.

Work ethic: use of appropriate equipment, practice basic skills, learn to use basic equipment, be accurate and be neat, proper care of equipment.

WE: follow instructions or directions in the performance of a specific task, set priorities or the order in which several tasks will be accomplished.

Communication: forms of communication, decode information, choosing forms of communication, sources of information, information retrieval systems.

C: read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information, compose logical and understandable written correspondence.

Task I 4

I.4 TASK: Use reference manuals to cross reference various electronic devices between manufacturers.

Science: identify variables, record and use data, systems, systems organization, use of keying systems, uses of knowledge to construct devices, criterial attributes, problem-solving, variables, parameters, taxonomy, variation, control variables, signal, transistor, voltage, band, characteristics, circuit board, frames of reference.

Mathematics: percent, similar, component, sequence, series, high, low, range, width, greater than, equal to, less than.

Work ethic: use of appropriate equipment, practice basic skills, learn to use basic equipment, be accurate and be neat, proper care of equipment.

WE: follow instructions or directions in the performance of a specific task, set priorities or the order in which several tasks will be accomplished.

Communication: forms of communication, decode information, choosing forms of communication, sources of information, information retrieval systems.

C: read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information, compose logical and understandable written correspondence.

Task I 5

I.5 **TASK:** Use manuals to determine maintenance procedures.

Science: organization, classification, patterns, properties of materials, theory, variation.

Mathematics: percent, time, period, periodic, cycle, length.

Work ethic: regular and proper care of equipment, proper use of equipment, learn basic requirements of job, keeping up-to-date, follow directions, practice basic skills, learn details about all equipment, attend to details, cross-check procedures, use of appropriate equipment, be accurate and be neat, proper care of equipment.

WE: follow instructions or directories in the performance of a specific task, set priorities or the order in which several tasks will be accomplished.

Communication: forms of communication, decode information, choosing forms of communication, sources of information, information retrieval systems.

C: read, understand, and find information or gather data from books, manuals, directories or other documents, read and understand graphs, charts, and tables to obtain factual information, compose logical and understandable written correspondence.

Task J 1

J.1 TASK: Distinguish between a manually-operated and automatically-operated control system.

Science: system, classification, variables, identify and control variables, circuits, predict, machines, motors, solid-state, switch, relay, dynamic, static, hybrid, interaction, function, open, closed, patterns, classification.

Mathematics: dichotomy, sort, similar, percent, part/whole relationships, operation.

Work ethic: follow instructions or directions in completion of a specific task.

Communication: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, or figures to obtain factual information.

Task J 2

J.2 TASK: Distinguish between an open and closed-loop control system.

Science: system, subsystem, schematic diagrams, classification, open closed, pattern, operational definition, work, interaction, organization, forces, motion, inertia, friction, circular motion, variation, feedback, action/reaction, relative position, identify and control variables.

Mathematics: dichotomy, sort, percent, spatial relations, circle, curves.

Work ethic: follow instructions or directions in completion of a specific task.

Communication: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, or figures to obtain factual information.

Task J 3

J.3 TASK: Explain the purpose of each of the blocks in a closed-loop control system (CLCS) block diagram.

Science: function, variables, identify and control variables, schematic diagram, open, closed, cycle, component, organization, input, output, signal, classification, error, feedback, interaction, compare and contrast, action/reaction, forces, signal, relative position, network, out-of-phase, polarity, transducer, amplifier, mechanical, electrical, hydraulic, pneumatic, theory.

Mathematics: percent, circle, time, set, subset, part/whole relationships, degree, opposite, amplitude, magnitude, combination, law, high, range.

Work ethic: follow instructions or directions in completion of a specific task.

Communication: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, or figures to obtain factual information.

Task J 4

J.4 TASK: State the characteristics of a good closed-loop control system. (CLCS)

Science: system, subsystem, components, function, use knowledge to construct devices, attributes, criterial attributes, circle, cycle, properties, characteristics, operational definition, classification, uses of knowledge, accurate, stable, rapid, input, signal, variation, relative position, voltage, speed, motion, load, forces, control variables, damper, overshoot, resistance, amplifier, switch, relay, schematic diagram, transducer.

Mathematics: rate, order, position, deviation, lessen, minimum, oscillate, null, opposite, zero, negative, conversion.

Work ethic: follow instructions or directions in completion of a specific task.

Communication: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, or figures to obtain factual information.

Task J 5

J.5 TASK: List and explain the operation and describe the characteristics of the five control modes for closed-loop control systems.

Science: system, identify and control variables, variables, characteristic properties, schematic diagram error, response, action/reaction, interaction, relative position, signal, observation, indicator, classification, parsimony, decision-making, precision, trade-offs, limitation, use of knowledge to construct devices, thermostat, solnoid, gas, valve, measurement, temperature, change, rise heat, energy, dissipate, input, output, state, band, reaction time, capacitor, current, voltage, potential difference, volts, prediction.

Mathematics: variation, mode, percent, time, point, integral, proportional, derivative, range, dichotomy, low, increase, decrease, level, cycle, oscillation, percentage, small, large, position, spatial relations, units of measurement, rate, constant, null, zero, primary, secondary.

Work ethic: follow instructions or directions in completion of a specific task.

Communication: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, or figures to obtain factual information

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Task J 6

J.6 TASK: Explain the operation of a Silicon Controlled Rectifier (SCR).

Science: silicon, element, properties of materials, rectifier, circuits, classification, thyristor, load, current, DC, operational definition, uses of knowledge, using knowledge to construct devices, indentify and control variables, power, energy, resistance, rheostat, variable, transformers, semiconductor, criterial attributes, systems, schematic diagram, symbols, problem-solving, bipolar, polar, transistor, series, switch, input, output, anode, cathode, ground, current, electrode, component, signal bias, short circuit, potential, voltage, conductor, sine wave, junction, potentiometer, voltage drop, wave forms, temperature, oscilloscope, wave form, theory, Ohm's Law, tolerance.

Mathematics: percent, time, attributes, large, small, rate, equivalent, sequence, internal, external, reverse, positive, negative, cycle, angles, number, degree, period, average, proportional, increase, decrease, dependent, independent, constant, constants, point, relative position, similar, units of measurement, kilo, decimals, mode, range.

Work ethic: follow instructions or directions in completion of a specific task.

Communication: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, or figures to obtain factual information.

J.7 TASK: Explain the operation of a Unijunction Transistor (UJT).

Science: electrical circuits, rectifier, load, current, use knowledge to construct devices, transistor, switch, identify and control variables, semiconductor, diode, resistance, pulse, schematic diagram, properties of materials, symbols, equivalent circuit, behavior of materials, bias, forward bias, variable, resistance, voltage, voltage divider, potential, ground, peak, limitation, capacitor, charge, control, current flow, waveforms, inhereut characteristics, oscilloscope, tolerance.

Mathematics: percent, time, value, low, high, negative, percentage, short circuit, curves, increase, rate, minimum, ratio, limits, range, delay.

Work ethic: follow instructions or directions in completion of a specific task.

Communication: read, understand, and find information or gather data from books, manuals, directories, or other documents, read and understand graphs, charts, or figures to obtain factual information.

J.8 TASK: Explain the operation of a TRIAC.

Science: electrical circuits, triode, switch, current, load, resistance, identify and control variables, uses of knowledge, alternating current, schematic diagram, symbol, terminal, function, anode, cathode, input, voltage, phase, polarity, source, waveforms, sine wave, characteristics of materials, behavior of materials, theory, current flow theory, conduction, half-cycle, variation, oscilloscope, forms of communication, resistor, tolerance.

Mathematics: lateral, bilateral, percent, similar, direction, dependent, curves, curve characteristics, angles, cycle, units of measurement, kilo, multiples, minimum, maximum, spatial relations.

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APPENDIX

B

CROSSWALK

ELECTRONIC CLUSTER MATRIX

CRT = Computer Repair Technician
EET = Electrical and Electronic Technician

APPLYING SAFETY PRACTICES

		CRT	EET	ELECTRONICS CURRICULUM
1	Apply basic emergency first aid techniques	X	X	
2	Complete accident report	X	X	
3	Inspect work area and equipment for safe working environment	X	X	
4	Report shop, environmental and equipment safety violations	X	X	
5	Demonstrate use of fire extinguishers	X	X	
6	Plan shutdown procedure for given area	X	X	
7	Participate in disaster control exercises	X	X	
8	Prepare plan for disaster control exercises	X	X	
9	Participate in shop safety committee	X	X	
10	Organize shop safety committee	X	X	
11	Correct safety hazards	X	X	
12	Demonstrate cardiopulmonary resuscitation (CPR) techniques	X	X	

ANALYZING DC CIRCUITS

		CRT	EET	
1	Read and interpret color codes	X	X	A-4
2	Analyze, construct and troubleshoot series circuits	X	X	A-7
3	Analyze, construct and troubleshoot parallel circuits	X	X	A-8
4	Analyze, construct and troubleshoot series-parallel circuits	X	X	A-9
5	Analyze, construct and troubleshoot voltage dividers	X	X	A-10
6	Analyze, construct and verify maximum power theory	X	X	A-6
7	Analyze, construct and troubleshoot resistance x capacitance (RC) and resistance x inductance (RL) circuits	X	X	A-13

ANALYZING AC CIRCUITS

		CRT	EET	
1	Set up and operate frequency counters and signal generators for AC circuits	X	X	B-1
2	Analyze, construct and troubleshoot AC capacitive circuits using a schematic	X	X	B-2
3	Analyze, construct and troubleshoot AC inductive circuits using a schematic	X	X	B-3
4	Analyze and apply principles of transformers to AC circuits using a schematic	X	X	B-4
5	Analyze, construct and troubleshoot resistor, capicitor and inductor (RCL) circuits using a schematic	X	X	B-6
6	Analyze, construct and troubleshoot series and parallel resonant circuits using a schematic	X	X	B-7
7	Analyze, construct and troubleshoot filter circuits using a schematic	X	X	B-8

ANALYZING SOLID STATE DEVICES

		CRT	EET	
1	Analyze, construct and troubleshoot simple common base amplifiers using a schematic	X	X	C-4
2	Analyze, construct and troubleshoot simple common emitters using a schematic	X	X	C-5
3	Analyze, construct and troubleshoot simple common collectors using a schematic	X	X	C-6
4	Examine field effect transistor (FET) characteristics	X	X	C-7

ELECTRONIC CLUSTER MATRIX

		CRT	EET	ELECTRONICS CURRICULUM
5	Analyze, construct and troubleshoot simple common sources using a schematic	X	X	C-8
6	Analyze, construct and troubleshoot simple common drains using a schematic	X	X	C-9
7	Analyze, construct and troubleshoot simple common gains using a schematic	X	X	C-10
8	Analyze, construct and troubleshoot thyristors using a schematic	X	X	C-11
9	Analyze, construct and troubleshoot integrated circuit operational amplifiers using a schematic	X	X	C-12
10	Analyze, construct and troubleshoot optoelectronic devices using a schematic	X	X	C-13

ANALYZING ANALOG CIRCUITS

		CRT	EET	
1	Analyze, construct and troubleshoot single-stage amplifiers using a schematic	X	X	D-1
2	Analyze, construct and troubleshoot multistage amplifiers using a schematic	X	X	D-2
3	Analyze, construct and troubleshoot basic power supplies, filters and regulators using a schematic	X	X	D-3
4	Analyze, construct and troubleshoot differential and operational amplifiers using a schematic	X	X	D-4
5	Analyze, construct and troubleshoot active filters using a schematic	X	X	D-6
6	Analyze, construct and troubleshoot oscillators using a schematic	X	X	D-7
7	Analyze, construct and troubleshoot basic pulse circuits using a schematic	X	X	D-8
8	Analyze, construct and troubleshoot basic modulation circuits using a schematic	X	X	D-9

ANALYZING DIGITAL ELECTRONIC CIRCUITS

		CRT	EET	
1	Analyze and troubleshoot basic digital logic gate integrated circuits using a schematic	X	X	
2	Verify basic Boolean expressions using basic logic gates	X	X	E-3
3	Analyze, construct and troubleshoot basic encoding and decoding circuits using a schematic	X	X	E-5
4	Analyze, construct and troubleshoot flip flops (memory) using a schematic	X	X	E-6
5	Analyze, construct and troubleshoot shift registers using a schematic	X	X	E-9
6	Analyze, construct and troubleshoot counters using a schematic	X	X	E-8
7	Analyze, construct and troubleshoot arithmetic circuits using a schematic	X	X	E-10
8	Analyze, construct and troubleshoot basic digital logic systems using a schematic	X	X	E-11

ELECTRONIC CLUSTER MATRIX

PERFORMING MICROPROCESSING OPERATIONS

		CRT	EET	ELECTRONICS CURRICULUM
1	Write, enter, verify and run simple machine language programs	X	X	F2-3
2	Write, enter, verify and run machine language arithmetic programs	X	X	F2-4, F1-3
3	Write, enter, verify and run machine language branching programs	X	X	F2-5, F1-5
4	Perform basic programming using algorithms	X	X	F2-6
5	Write, enter, verify and run machine language program using additional addressing modes	X	X	F2-8
6	Perform basic programming using branching, algorithms and flow charting	X	X	F1-7
7	Perform basic programming to demonstrate computer arithmetic	X	X	F1-3, F2-4
8	Prepare simple program to demonstrate operation of microprocessor unit (MPU) stack, subroutines, input/output (I/O) and interrupts	X	X	F1-8
9	Prepare simple program to perform interface operations with random access memory (RAM) and display	X	X	F2-12, F1-9
10	Prepare simple program to perform interface operations with switches and light emitted diodes (LEO's)	X	X	F1-10
11	Interface analog to digital converters to microprocessor	X	X	F2-15, F1-12
12	Interface digital to analog converters to microprocessor	X	X	F2-15, F1-11

PERFORMING LAB PRACTICES

		CRT	EET	
1	Assemble printed circuit (PC) board	X	X	G-7
2	Solder wires to turret terminals and printed circuit (PC) boards	X	X	G-8
3	Assemble and solder printed circuit (PC) board	X	X	G-9
4	Repair printed circuit (PC) board	X	X	G-10
5	Set up and operate scales	X	X	G-13
6	Set up and operate mechanical and optical measuring devices	X	X	G-19
7	Set up and operate height gauges	X	X	G-20
8	Set up and operate depth gauges	X	X	G-21
9	Set up and operate oscilloscopes	X	X	G-24
10	Set up and operate multimeter and power supplies	X	X	G-25
11	Set up and operate capacitor inductor analyzers	X	X	G-27
12	Set up and operate semiconductor testers and curve tracers	X	X	G-28
13	Set up and operate chart recorder	X	X	
14	Set up and use digital test equipment	X	X	G-30

RECORDING AND REPORTING TECHNICAL MATERIAL

		CRT	EET	
1	Record data and design curves and graphs	X	X	H-1
2	Write reports	X	X	H-2
3	Make equipment failure reports	X	X	H-3
4	Specify and requisition simple electronic components	X	X	H-4
5	Write formal reports of laboratory experiences	X	X	H-6

USING TECHNICAL REFERENCES

		CRT	EET	
1	Identify manufacturers of various electronic devices using numerical integrated circuit (IC) reference manuals	X	X	I-1
2	Identify specific characteristics of various electronic devices using manufacturers' reference manuals	X	X	I-2

ELECTRONIC CLUSTER MATRIX

	CRT	EET	ELECTRONICS CURRICULUM
3 Identify distributors of various electronic devices using reference manuals	X	X	I-3
4 Cross-reference various electronic devices between manufacturers using reference manuals	X	X	I-4
5 Determine maintenance procedures using manuals	X	X	I-5

MAINTAINING AND REPAIRING ELECTRICAL SYSTEMS

	CRT	EET
1 Replace faulty electrical cords and plugs	X	X
2 Determine electrical problems using available troubleshooting techniques	X	X
3 Interpret control diagrams for electrical systems	X	X
4 Diagnose malfunctions of electrical systems using available test and measurement equipment	X	X

MAINTAINING AND REPAIRING ELECTRONIC SYSTEMS

	CRT	EET
1 Determine electronic problems using available troubleshooting techniques	X	X
2 Interpret control diagrams for electronic systems	X	X
3 Diagnose malfunctions of electronic systems using available test and measurement equipment	X	X

CONDUCTING SHOP OPERATIONS

	CRT	EET
1 Answer customer questions	X	X
2 Troubleshoot customer problems	X	X
3 Determine repair method	X	X
4 Perform public relations activities	X	X
5 Demonstrate computer equipment functions at store	X	X
6 Demonstrate software functions	X	X
7 Prepare service bill	X	X
8 Maintain accounts receivable/paid records	X	X
9 Maintain receiving records	X	X
10 Maintain shipping records	X	X
11 Maintain records of service tools and equipment	X	X
12 Maintain computer equipment inventory	X	X
13 Maintain call record report	X	X
14 Update on-site maintenance log	X	X
15 Unpack and inspect new equipment	X	X
16 Receive and store parts and supplies	X	X
17 Discuss delivery schedule with approved supplier	X	X
18 Order parts and supplies	X	X
19 Establish customer and equipment history file	X	X
20 Establish customer files	X	X
21 Prepare items for shipping	X	X
22 Update service manuals	X	X
23 Update parts catalogs	X	X
24 Modify wiring diagrams to reflect repair changes	X	X

PERFORMING HOUSEKEEPING AND RECORDKEEPING

	CRT	EET
1 Clean and maintain work area and leave in safe condition	X	X
2 Follow tool crib procedures	X	X
3 Report problems to supervisor	X	X

ELECTRONIC CLUSTER MATRIX

		CRT	EET	ELECTRONICS CURRICULUM
4	Complete time cards	X	X	
5	Complete job status reports	X	X	
6	Make equipment failure reports	X	X	
7	Use manuals to determine basic maintenance procedures	X	X	
8	Participate in participation management program (Quality Circles)	X	X	

PERFORMING SUPERVISORY FUNCTIONS

		CRT	EET
1	Determine availability of machines, supplies and materials	X	X
2	Requisition, schedule and distribute supplies and materials	X	X
3	Coordinate workers with work to be done	X	X
4	Schedule and control shop flow of jobs	X	X
5	Maintain files	X	X
6	Maintain service records	X	X
7	Maintain labor records	X	X
8	Explain work requirements	X	X
9	Write technical reports	X	X
10	Inventory supplies and equipment	X	X
11	Maintain charts, tables, graphs or status boards on work scheduled	X	X
12	Check job/time cards	X	X
13	Inspect shop equipment and arrange for maintenance and work	X	X
14	Coordinate maintenance and repair of shop equipment	X	X
15	Develop preventative maintenance program	X	X
16	Plan and implement technical training for employees	X	X
17	Train new service technicians	X	X
18	Evaluate employee progress and performance	X	X
19	Follow up employee reports of problems or equipment failures	X	X
20	Interview job applicants	X	X
21	Estimate cost of equipment installation	X	X
22	Estimate cost of system installation	X	X
23	Estimate cost of maintenance repairs and downtime	X	X
24	Conduct representative meetings	X	X

INSTALLING COMPUTER EQUIPMENT

		CRT	EET
1	Determine customer computing requirements	X	
2	Design computer system layout	X	
3	Transport computer equipment	X	
4	Set up computer equipment	X	
5	Perform computer installation tests	X	
6	Demonstrate usage of computer system on-site	X	
7	Complete warranty cards for computer equipment	X	
8	Construct cables for computer equipment	X	

EVALUATING COMPUTER DIAGNOSTICS

		CRT	EET
1	Conduct motherboard random access memory (RAM) test	X	
2	Conduct motherboard read only memory random access (ROM) test	X	
3	Conduct programmers' aid test	X	
4	Conduct computer keyboard test	X	
5	Conduct computer paddle/button test	X	

ELECTRONIC CLUSTER MATRIX

	CRT	EET	ELECTRONICS CURRICULUM
6 Conduct computer tape read/write/verify test	X		
7 Conduct computer color bar test	X		
8 Conduct computer graphic tablet test	X		
9 Conduct basic/integer read only memory (ROM) card test	X		
10 Conduct computer language card test	X		
11 Conduct computer disk interface card test	X		
12 Conduct computer printer card test	X		
13 Conduct computer serial communication card test	X		
14 Conduct computer monitor test	X		
15 Conduct computer oscilloscope test	X		
16 Conduct computer data communication line test	X		
17 Interpret computer diagnostic flow charts	X		

MAINTAINING COMPUTER EQUIPMENT

	CRT	EET
1 Clean metallic computer parts	X	
2 Clean nonmetallic computer parts	X	
3 Clean electrical connections in computer	X	
4 Clean computer cable connections	X	
5 Clean printer head	X	
6 Clean computer disk drive head	X	
7 Clean and demagnetize computer tape head	X	
8 Lubricate metallic mechanical computer parts	X	
9 Lubricate nonmetallic mechanical computer parts	X	
10 Adjust mechanical computer assemblies	X	
11 Adjust and align computer disk drive head	X	
12 Adjust and align computer tape head	X	
13 Set computer disk read/write/verify speed	X	
14 Set computer tape read/write/verify speed	X	
15 Clean or replace computer filters	X	
16 Clean outside case/cover of computer	X	

SERVICING COMPUTER EQUIPMENT

	CRT	EET
1 Interpret computer troubleshooting charts	X	
2 Interpret chip-swapping charts	X	
3 Interpret computer schematics	X	
4 Interpret manufacturing upgrade	X	
5 Remove and install computer cover	X	
6 Install computer keyboard	X	
7 Install motherboard in computer	X	
8 Install power supply in computer	X	
9 Install analog board in computer	X	
10 Install disk drive assembly in computer	X	
11 Install main logic assembly in computer	X	
12 Install integrated circuit chips in computer	X	
13 Install power light in computer	X	
14 Install on-off switch in computer	X	
15 Install main printed circuit board in computer	X	
16 Install power supply printed circuit board in computer	X	
17 Install drive motor	X	
18 Install print hammer	X	
19 Install print mechanism	X	
20 Install carriage assembly	X	
21 Install paper feed assembly	X	

ELECTRONIC CLUSTER MATRIX

		CRT	EET	ELECTRONICS CURRICULUM
22	Install drive indicator light	X		
23	Install peripheral connection cables	X		
24	Install peripheral connections	X		
25	Install circuit/language cards	X		
26	Install modem coupler	X		
27	Install tape transport assembly	X		
28	Install read/write/verify head	X		
29	Install modem set switch	X		
30	Install ribbon assembly	X		
31	Install drive belts	X		
32	Install AC input connections	X		
33	Install fuse holders and fuses	X		
34	Install ejector mechanisms	X		
35	Install cathode ray tube	X		
36	Install configuration switches	X		
37	Install peripheral controls	X		
38	Install data communications adaptor	X		
39	Install expansion memory	X		
40	Install main memory	X		
41	Install field type product line	X		
42	Install remote terminals	X		
43	Install electrical wiring	X		
44	Install keys on keyboard	X		
45	Repair keyboard	X		
46	Repair motherboard	X		
47	Repair analog board	X		
48	Repair disk drive assembly	X		
49	Repair logic assembly	X		
50	Repair on-off switch	X		
51	Repair mechanical assembly	X		
52	Repair printed circuit board	X		
53	Repair drive motor	X		
54	Repair carriage assembly	X		
55	Repair paper feed assembly	X		
56	Repair circuit/language card	X		
57	Repair tape transport assembly	X		
58	Repair print mechanism	X		
59	Repair read/write/verify head	X		
60	Repair ribbon assembly	X		
61	Repair ejector mechanism	X		
62	Repair peripheral controls	X		
63	Repair data communications adaptor	X		
64	Repair expansion memory	X		
65	Repair memory	X		
66	Repair field type product line	X		
67	Repair remote terminals	X		
68	Identify integrated circuit chips	X		
69	Identify machine components and test points	X		
70	Set configuration switches	X		
71	Set user switches	X		
72	Install mechanical assembly	X		
73	Perform operator duties	X		

ELECTRONIC CLUSTER MATRIX

	CRT	EET	ELECTRONICS CURRICULUM
74 Realign read/write/verify head	X		
75 Adjust motor speed	X		
76 Check AC power source	X		
77 Repair power supply	X		

APPENDIX

C

EMPLOYABILITY SKILLS

EMPLOYABILITY SKILLS

DUTY A: Identifying Employment Opportunities

SKILLS:
1. Identify requirements for job
2. Investigate educational opportunities
3. Investigate occupational opportunities
4. Locate resources for finding employment
5. Confer with prospective employers
6. Identify job trends

DUTY B: Applying Employment Seeking Skills

SKILLS:
1. Locate job openings
2. Document skills and abilities (resume)
3. Prepare for interview
4. Participate in interview
5. Complete required tests
6. Complete required forms
7. Write application letter
8. Write follow-up letter
9. Write acceptance letter
10. Evaluate job offer
11. Evaluate job rejection

DUTY C: Interpreting Employment Capabilities

SKILLS:
1. Match interest to job area
2. Match aptitudes to job area
3. Verify abilities
4. Identify immediate work goal
5. Develop career plan

DUTY D: Demonstrating Appropriate Work Behavior

SKILLS:
1. Exhibit dependability
2. Demonstrate punctuality
3. Follow rules and regulations
4. Recognize the consequences of dishonesty
5. Complete assignments in accurate and timely manner
6. Control emotions
7. Assume responsibility for own decisions and actions
8. Exhibit pride and loyalty
9. Exhibit ability to handle pressures and tensions
10. Demonstrate ability to set priorities
11. Demonstrate problem-solving skills

DUTY E: Maintaining Safe and Healthy Environment

SKILLS:
1 Comply with safety and health rules
2 Select correct tools and equipment
3 Utilize equipment correctly
4 Use appropriate action during emergencies
5 Maintain clean and orderly work area
6 Demonstrate personal hygiene and cleanliness

DUTY F: Maintaining Business-Like Image

SKILLS:
1 Paticipate in company or agency orientation
2 Demonstrate knowledge of company or agency products and services
3 Exhibit positive behavior
4 Read current job-related publications
5 Support and promote employer's company image and purpose
6 Maintain appearance to comply with company standards

DUTY G: Maintaining Working Relationships with Others

SKILLS:
1 Work productively with others
2 Show empathy, respect and support for others
3 Demonstrate procedures and assist others when necessary
4 Recognize, analyze and solve or refer problems
5 Minimize occurence of problems
6 Channel emotional reaction constructively

DUTY H: Communicating on the Job

SKILLS:
1 Read and comprehend written communications and information
2 Use correct grammar
3 Speak effectively with others
4 Use job-related terminology
5 Listen attentively
6 Write legibly
7 Use telephone etiquette
8 Follow written and oral directions
9 Ask questions
10 Locate information in order to accomplish task
11 Prepare written communication
12 Utilize keyboarding skills
13 Utilize computer skills

DUTY I: Adapting to Change

SKILLS:
1 Recognize need to change
2 Demonstrate willingness to learn

3 Demonstrate flexibility
4 Participate in continuing education
5 Seek worth challenges
6 Adjust career goals/plan as needed

DUTY J: Understanding How a Business Works

SKILLS: 1 Recognize the role of business in the enterprise system
2 Identify general responsibilities of employees
3 Identify general responsibilities of management/employers
4 Investigate opportunities and options for business ownership
5 Identify planning processes needed to open a business
6 Participate in meetings

DUTY K: Performing Mathematical Skills

SKILLS: 1 Apply mathematics for problem solving
2 Add and subtract whole numbrs, decimals and fractions
3 Multiply and divide whole numbers, decimals and fractions
4 Convert numbers between forms expressed as fractions, decimals and percents
5 Convert between standard American units of measure
6 Convert between standard American units and metric units

Employability skills are a vital component of vocational education programs and should be incorporated into each occupational task list.